DOCUMENT RESUME

ED 335 235 SE 052 227

AUTHOR	Blosser, Patricia E., Ed.; Helgeson, Stanley L., Ed.
TITLE	National Association for Research in Science Teaching Annual Conference Proceedings (63rd, Atlanta, Georgia, April 8-11, 1990). Abstracts of Presented Papers.
INSTITUTION	ERIC Clearinghouse for Science, Mathematics, and Environmental Education, Columbus, Ohio.; National Association for Research in Science Teaching.
SPONS AGENCY	Office of Educational Research and Improvement (ED), Washington, DC.
PUB DATE	Apr 90
NOTE	199p.
PUB TYPE	Collected Works - Conference Proceedings (021)
EDRS PRICE	MF01/PC08 Plus Postage.
DESCRIPTORS	*Academic Achievement; Biology; Chemistry; Cognitive Processes; *College Science; Computer Assisted Instruction; Concept Formation; Curriculum Development; *Elementary School Science; Elementary Secondary Education; Foreign Countries; Higher Education; Learning Strategies; Misconceptions; Physics; Problem Solving; Process Education; Science and Society; Science Curriculum; Science Education; Science Instruction; Science Teachers; *Secondary School Science; Sex Differences; Skill Development; Student Attitudes; Teacher Education; Teaching Methods; Technology
IDENTIFIERS	*Constructivism; *Science Education Research

ABSTRACT

This document contains the abstracts of most of the papers, symposia, and poster sessions presented at the 63rd Annual Conference of the National Association for Research in Science Teaching (NARST). Subject areas addressed include teacher preparation; informal settings; cognitive models; classroom practices; teaching methods; student learning; teacher beliefs; microcomputers; elementary science; cooperative learning; teacher knowledge; visual learning; science instruction; science curriculum; self-efficacy; problem solving; gender; teacher programs; student thinking; research in Norway, Costa Rica, Taiwan, and Africa; science/technology/society; individual differences; electronic learning; cognitive test development; cognitive change; teacher development; and attitudes. (KR)

ABSTRACTS OF PRESENTED PAPERS

The National Association for Research
in Science Teaching

in cooperation with

SMEAC Information Reference Center
The Ohio State University
1200 Chambers Road, Room 310
Columbus, OH 43212

ERIC Clearinghouse for Science,
Mathematics, and Environmental Education
The Ohio State University
1200 Chambers Road, Room 310
Columbus, OH 43212

NATIONAL ASSOCIATION FOR RESEARCH IN

SCIENCE TEACHING - 63rd ANNUAL NARST CONFERENCE

Atlanta, Georgia

April 8-11, 1990

March, 1990

This publication was prepared pursuant to a contract with the Office of Educational Research and Improvement, U.S. Department of Education. Contractors undertaking such projects under government sponsorship are encouraged to express freely their judgement in professional and technical matters. Points of view or opinions, however, do not necessarily represent the official views or opinions of the Office of Educational Research and Improvement.

PREFACE

The SMEAC Information Reference Center for Science, Mathematics, and Environmental Education has cooperated with the National Association for Research in Science Teaching to provide abstracts of most of the papers presented at the 63nd annual conference in Atlanta, Georgia, April 8-11, 1990.

All persons who had papers or symposia accepted were invited to submit abstracts for inclusion in this publication. Some editing was done by the ERIC staff to provide a general format for the abstracts.

Everyone presenting a paper at this conference is encouraged to submit to the ERIC Clearinghouse for Science, Mathematics, and Environmental Education a copy of their paper to be considered for inclusion in the ERIC data base. A submission form is included on page iii of this publication. Papers which are not submitted cannot be included in ERIC.

Many of the papers will be published in journals or made available through the ERIC system. These will be announced through Resources in Education, Current Index to Journals in Education, and other publications of the ERIC system.

Patricia E. Blosser
Stanley L. Helgeson
Editors

Preface i

Including your Paper in ERIC ii

ERIC Reproduction Release Form iii

PAPERS PRESENTED AT THE CONFERENCE

Symposium

"Establishing Training Centers for Inservice Science Teachers"
James D. Ellis, Phil Goulding, Janet C. Powell,
Michael R. Hannigan and Cecilia Lenk 1

Panel

"Exploration of Opportunities in Informal Settings for Synthesis of Teacher Preparation, Exhibit Evaluation, and Research"
Charles R. Ault, Jr., Michael R. Cohen, Linda Furuness,
Deborah L. Perry and Piyush Swami 3

Contributed Papers - Cognitive Models

"A Hierarchical-Network Model of Cognitive Structure: Applications to Science Content Analyses"
O. Roger Anderson 5

"Integration of Domain Specific Knowledge and General Strategies in Solving Novel Problems in the School Science Laboratory"
Pinchas Tamir 6

"Hypothetico-Deductive Reasoning and Concept Acquisition: A Test of the Constructivist Hypothesis"
Anton E. Lawson 6

Contributed Papers - Classroom Practices

"Relationship Between Subject Matter Structure and Social Classroom Interactions in High School Physics"
Armando Contreras 8

"Curriculum and Instructional Practice in the Physics, Chemistry, Biology and General Science Classrooms"
Wilmad A.J.M. Kuiper and Annita Alting 9

"Science Instruction for the Mildly Handicapped: Direct Instruction Versus Discovery Teaching"
John R. Staver, Mary Bay, Tanis Bryan, and
James B. Hale 10

Contributed Papers - Teacher Teaching Strategies

"Survey of Factors that Stress Science Teachers and an Examination of Coping Strategies"
Peter Okebukola and Olugbemiro J. Jegede 11

"Teacher Knowledge and the Language of Science Teaching"
William S. Carlsen 12

"Teacher Personal Practical Theories and their Influence Upon Teacher Curricular and Instructional Actions: A Case Study of a Secondary Science Teacher"
Catherine G. Yeotis and Jeffrey W. Cornett 12

Contributed Papers - Student Learning

"The Use of Concept Maps in Examining Students' Conceptions and Structure of Knowledge in Science"
Josephine D. Wallace and Joel J. Mintzes 14

"An Analysis of Student Interactions and Behaviors During Problem Solving Within the SSCS Instructional Model Utilizing Path Analysis"
Daniel P. Shepardson and Edward L. Pizzini 15

"Students' Intuitive Ideas About "Water in the Atmosphere": A Cross Age Study"
Chan-Jong Kim and James P. Barufaldi 15

"Students' Perceptions of the Nature of Science: Assessment, Development, and Sources of Change"
Norman G. Lederman 17

Symposium

"Charting New Directions for Science Education in the Middle Grades"
Paul J. Kuerbis, Rodger W. Bybee, Audrey B. Champagne, and Michael Padilla 19

Paper Set

"The Use of Microcomputers to Aid in Teaching Graphics: Analysis, Software Design and Student Response Analysis"
David Jackson, Carl F. Berger and Billie Edwards 21

Contributed Papers - Teacher Beliefs

"The Influence of Teachers' Personal Epistemologies, Beliefs, and Role Metaphors on Assessment Practices"
Carol Briscoe, Anthony G. Lorsbach, Kenneth Tobin and Sarah L. Ulerick 23

"Teacher Perceptions and Opinions Concerning the Implementation of an Inquiry-Oriented Secondary Biology Course"
David F. Treagust and Ian Sydney-Smith 24

"Science Teachers' Attitudes and Beliefs About the Effectiveness of Writing for Learning and Teaching Science"
Karen Sullenger 25

Contributed Papers - Elementary Science

"A Curriculum Strategy that Expands Time for In-Depth Elementary Science Instruction by Using Science-Based Reading Strategies: Effects of a Year-Long Study in Grade Four"
Nancy R. Romance and Michael R. Vitale 27

"How the Design of Instructional Materials Can Further the Implementation of an Elementary Science Curriculum"
Jan J.H. Van Den Akker 27

"Either/Or = Neither/Nor: Case Study on the Implementation of a Problem Solving Curriculum in Elementary Science"
Mary Lee Martens 29

Contributed Papers - Cooperative Learning

"Learning Biology in a Cooperative Mode in Ninth Grade Heterogeneous Classrooms: Students' Achievements by Method and Gender"
Reuven Lazarowitz and Miri Galon 31

"Cognitive Conflict and Cooperative Learning"
Gail Jones 32

"Cooperative Learning and Group Educational Modules: Effects on Cognitive Achievement of High School Biology Students"
Scott B. Watson 32

"A Descriptive Study of Life and Physical Science Alternative Concepts of Preservice Elementary Teachers"
Sophia Yani Arditzoglou and Frank E. Crawley 33

Contributed Papers - Teacher Knowledge

"The Effect of Confidence and Effectiveness on the Biology Content Cognitive Structure of Teachers"
Patricia L. Hauslein and Ronald Good 34

"A Comparative Study of the Pedagogical Content Knowledge of Experienced and Novice Chemical Demonstrators"
Christian P. Clermont, Hilda Borko and Joseph S. Krajcik 35

"The Nature of Verbal Explanations Given by Science Teachers"
Zoubeida Dagher and George W. Cossman 36

Symposium

"A Cross-National Study of Science Laboratory Classroom Environments"
Barry J. Fraser, Geoff J. Giddings, Avi Hofstein, Alan K. Griffiths and Dale G. Merkle 38

Contributed Papers - CAI/Visual Learning

"An Investigation of the Relationship Between Logical Thinking Structures and the Ability to Construct and Interpret Line Graphs"
Craig A. Berg 40

"The Effect of Simultaneous Motion Presentation and Graph Generation in a Kinematics Lab"
Robert J. Beichner 41

"The Exhibit Interpreter: An Attention-Focuser in Science Museums"
Elizabeth M. Bennett and Ertle Thompson 41

"Hierarchical Levels of Difficulty for Test Items with Visual Illustrations"
Edith Yi-Tan Chang 42

Contributed Papers - Teachers and Instruction

"Changing the Conversation: When Science Teachers Start Talking About Instruction..."
Antonio Bettencourt and James J. Gallagher 44

"Expanding Middle School Science Teachers' Role Conceptualizations Through Collaboration and Reflection"
Sarah L. Ulerick and Anthony W. Lorsbach 45

"Constructivist Ideas as a Basis for Inservice Teacher Education: First Year Results of a Program to Enhance Middle School Understanding of Target Concepts in the Area of Electricity and Simple Circuitry"
James A. Shymansky, John Dunkhase, Obed Norman, Hui Ju Huang, Chin Tang Liu, Charles Matthews and Zoubeida Dagher. 46

Contributed Papers - Curriculum and Instruction

"An Exploratory Study of a Play-Based Center Approach to Learning Chemistry in an Early Childhood Program"
John T. Norman and Thomas E. Taddonio 48

"Applied and Theoretical Knowledge of Chemistry Concepts"
Michael R. Abraham and Abdullateef H. Haidar 49

"Science Activities Children Choose Outside the School: A Descriptive Study with Implications for Classroom Instruction"
Elisabeth Charron 50

Contributed Papers - Self-Efficacy and Learning

"Further Development of an Elementary Science Teaching Efficacy Belief Instrument: A Preservice Elementary Teacher Scale"
Larry G. Enochs and Iris M. Riggs 51

"Attitude and Secondary School Science Students' Intention to Enroll in Physics: An Application of the Theory of Planned Behavior"
Frank E. Crawley and Carolyn B. Black 51

"Using Science Activities to Internalize Locus of Control and Influence Attitudes Towards Science"
Paul McD Rowland 52

"A Study of Self-Efficacy, Anxiety, and Science Knowledge in Preservice Elementary Teachers"
Charlene M. Czerniak 53

Symposium

"Research on Sustaining Authentic Science in Elementary Schools"
Ronald D. Anderson, James Gallagher, Carole P. Mitchener, Kenneth Tobin and Deborah Muscella 55

Paper Set - Computers, Technology and Problem Solving

"Representation and Feedback in the Formation of a Chemical Concept"
Patricia Iuele 56

"Metacognitive Behavior of Novice Biology Students"
Lavinia Kumar 57

"Computer Technology: The Dynamic Problem Presentation Interfaced with Three Instructional Modes"
Sheila Pirkle and Jeffrey Correll 58

"Simulation and Student Representation in Solving Kinematics Problems"
Alan Naimoli and George Pallrand 58

"Feedback: A Mechanism in Modeling Cognition"
Frank Gagliardi 59

Contributed Papers - Gender and Science I

"Gender, School Type and Science Achievement of Elementary Students...Are They Related?"
Pamela Fraser-Abder 60

"Gender Differences in Examination Type Preferences, Test Anxiety, and Academic Achievements in College Science Education - A Case Study"
Uri Zoller and David Ben-Chaim 60

"The Use of Empirical Versus Subjective Procedures for Identifying Science Test Items which Discriminate Against Females or Males"
Richard R. Tolman and Richard Sudweeks 62

Contributed Papers - Prospective Teacher Programs

"The Effects of an Innovative Activity-Centered Biology Program on Attitude Toward Science Teaching Among Preservice Elementary Teachers"
Donald A. Hall 63

"Affecting Preservice Elementary Teachers' Attitudes Toward Inquiry Teaching in Science Through Projects with Individual Children"
Larry Flick 64

"The Influence of Different Instructional Designs on Preservice Elementary Teachers"
Yu-Jiing Shyu 64

Contributed Papers - Student Thinking

"Thinking Processes Model: Effect on Logical Reasoning Abilities of Students in Grades Six Through Twelve"
Betty L. Bitner 66

"Student Thinking in Advanced Placement and General Biology Classes"
J. Hugh Baird and Jennifer Schuyler 67

"What Students Need and do to Become Successful Learners: An Information-Constructivist Perspective of School Learning"
Robert J. Stahl 67

Posters - Learners and Learning

"An Assessment of what Grade 5 Students Know About Science Text and Science Reading"
Larry D. Yore and Madge T. Craig 69

"Influencing Leadership in Seventh Grade Life Science Classrooms"
Mary M. Atwater, David Butts, Patricia Simmons and Rosalina Hairson 70

"The Effects of an Extended Case Study on Citizenship Behavior and Associated Variables in Fifth and Sixth Grade Students"
Patricia R. Simpson 71

"A Plant Identification Task - Avoidance Patterns in Children"
Delena Tull 71

"Readiness to Learn College Physics"
Arnold Paltzer 73

"A Comparative Study of Target and Nontarget Students"
C. Thomas Gooding, Michelle M. Kephart, Mary A. Connery, J. Nathan Swift, Patricia R. Swift and Robert E. Schell 74

"Alternative Physical Science Conceptions, Science Achievement and Formal Reasoning Ability of Students in Grades Eight Through Twelve"
Thomas G. Teates, George E. Glasson and Edgar D. Morris, Jr. 75

"An Evaluative Study of Level One Instructional Videodisc Materials Used in Science Classrooms"
Robert D. Sherwood, Ted S. Hasselbring and E. Jean Marsh 76

"The Validation of the Physical Science Misconceptions Test"
Hsiung Tung-Hsing and Joseph P. Riley 77

Symposium

"Role of the Epistemic Subject in Piaget's Genetic Epistemology and Its Importance for Science Education"
Mansoor Niaz, Anton E. Lawson, Richard F. Kitchener and Joseph Novak 78

Contributed Papers - Prospective Teacher Learning

"Science Teaching and Learning: Using Concept Mapping to Develop Reflective Practitioners"
Cheryl L. Mason 80

"Cooperative Learning in a College Science Course for Preservice Elementary Teachers"
Diana C. Rice and Dorothy Gabel 81

Contributed Papers - Secondary/Postsecondary Teaching

"Comparison of a Hands-On with a Remediation-Based Approach to Teaching a Community College Biology Preparatory Course"
Carol A. Biermann and Gary B. Sarinsky 83

"Replacing Traditional Specimen-Based Lab Practicals with Projection Slide-Based Lab Practicals"
Thomas R. Lord 83

"The Effects of a Diagnostic and Prescriptive Instructional Strategy on the Achievement of High School Students Learning Science From Text"
Pierce Farragher 84

"Metamorphosis, Adaptation, or Evolution?: A Longitudinal Investigation of Preservice Science Teachers' Instructional Decisions, Concerns, and Perceptions"
Julie Gess-Newsome and Norman G. Lederman 85

Contributed Papers - Computers and Visual Modes

"The Effect of Two Modes of Sensory Input on Children's Retention and Recall"
Ann C. Howe and Ellen S. Vasu 87

"The Effects of CAI and Hands-On Activities on Elementary Students' Attitudes and Weather Knowledge"
Cathy Gardener and Patricia E. Simmons 88

"Scientific Reasoning and Problem Solving Skills Exhibited by Students Using Computer Simulation Programs"
Willis J. Horak and Virginia M. Horak 89

Contributed Papers - Learning and Language

"Interpreting the Learning Cycle From a Language Learning Perspective"
George E. Glasson and Rosary V. Lalik 90

"The Effects of Controversial Issues on the Level of Written Prose"
Jon E. Pedersen 90

"TLTG Interactive Videodisc Physical Science Program: Results of the 1988-89 Field Test"
Dava C. Coleman, Thomas R. Koballa, Jr. and Frank E. Crawley 91

Posters - Prospective Teachers and Instruction

"Further Validation of a Preservice Elementary Science Efficacy Belief Instrument: The Contribution of Pupil Control Ideology"
Larry G. Enochs, Larry C. Scharmann, and Iris Riggs 93

"The Effects of Hands-On Science Instruction on Preservice Elementary Teachers' Cognitive Structures as Measured by Concept Maps"
Priscilla L. Callison, Emmett Wright, Girish Govindarajan, Don Powers and Cindy Ford 94

"Identification of Variables Affecting the Development of Scientific Reasoning Abilities in Elementary Education Majors"
Carol L. Stuessy and Rebecca J. Pollard 95

"A Preliminary Analysis of Preservice Teacher Perceptions of Effective Teaching"
Cynthia T. Holland and Linda Cronin-Jones 96

"An Assessment of Preservice Teachers' Knowledge of Environmental Problems and Concerns for Environmental Quality in Botswana"
Modise Mosothwane and Joseph P. Riley II 97

"Learning to Teach: Choices vs Constraints"
Zurida Ismail and Annette Larussa 98

"An Examination of Elementary Science Methods Textbooks 1900-1989"
Sandra K. Abell 99

"Learning Patterns of College Students Using an Intelligent Computer Assisted Instruction Tutorial in Endocrinology"
Yehudit Judy Dori and Jerome M. Yochim 99

"Using Computer/Laser Disk Interface to Teach Earth Science/Astronomy to Undergraduate Classes"
Pier e Farragher 100

"Constructing Meaning in Learning and Teaching Science with Prospective Teachers"
Pamela Engler and Jere R. Holman 101

Symposium

"The Prospects for Change in Middle School Science Education"
Janet Carlson Powell, Rodger W. Bybee, M. Jean Young and William C. Robertson 102

Contributed Papers - International Curriculum Studies

"Qualitative Study of Science in Norwegian Elementary Schools"
Doris Jorde 103

"Teachers' Implementation of a National Curriculum: A Case Study of Science Teacher's of Costa Rica"
Alejandro J. Gallard 103

"Attitude and Achievement of Students in an Environment Dominated by Indigenous Technology to the Use of the Computer for Learning Biological Concepts"
Olugbemiro Johnson Jegede, Peter Akinsola Okebukola' and Gabriel Ajewole 104

Contributed Papers - Science/Technology/Society

"Fourth, Eighth and Eleventh Grade Students' Understanding of Pollution"
Michael J. Brody 106

"The Effects of STS Issue Investigation and Action Instruction and Traditional Life Science Instruction on Seventh Grade Students' Citizenship Behaviors"
Randall L. Wiesenmayer and Peter A. Rubba 106

"A Study of the Qualities Teachers Recommend in STS Issue Investigation and Action Instructional Materials"
Peter A. Rubba and Randall L. Wiesenmayer 107

Contributed Papers - Prospective Teacher Beliefs

"What do Prospective Science Teachers Understand About the Nature of Science?"
Michael J. Wavering 109

"Preservice Preconceptions in Science"
Bruce Gurney 110

"Perceived Sources of Legitimation Among Preservic Secondary Science Teachers"
Annette LaRussa 111

Posters - Individual Differences and Structures

"Children's Mental Models of Gravity and Their Predictions of the Vertical Motion of Objects"
J. E. White and Shawn M. Glynn 113

"A Comparative Analysis of Boys' and Girls' Perceptions of Scientists Based on their Drawings"
J. Nathan Swift, Donna Waick, Robert E. Schell, C. Thomas Gooding and Patricia R. Swift 114

"An Investigation of the Differences in Attitude and Achievements Between Male and Female Second and Fifth Grade Science Students"
Edward L. Shaw, Jr. and Robert L Doan 115

"A Logico-Structural, Worldview Analysis of the Interrelationship Between Science Interest, Gender, and Concept of Nature"
William W. Cobern, Jane E. Ellington and Daniel M. Schores 116

"Measuring Equity in the Science Classroom: A New Tool"
Lynnette Danzl-Tauer 116

"The Development of a Gender Environment Scale"
Kathryn Scantlebury 117

"Differences in the Perception of the Science Curriculum by Teachers and Students: And their Implications for the Development of Attitude"
Michael D. Piburn 118

"Perceived Encouragement or Discouragement in the Use of Hands-On Activities in Science and the Impact on Teaching Styles"
Betty Crocker, Edward L. Shaw, Jr. and Barbara Reed 119

"Student Recall and Attitude from Reading Textbook Passages about Insects that Reflect Different Themes of Scientific Literacy"
David A. Fillman and Eugene L. Chiappetta 120

"Genetics Misconceptions in High School Biology Textbooks"
Nancy D. Green Glenn 121

Symposium

"Science Teachers' Use of Analogies: Potential and Practice"
David F. Treagust, Reinders Duit, Paul Joslin
and Ivo Lindauer 123

Contributed Papers - Electronic Learning

"Integrating Computer Interfaced Videodisc in
College Introductory Biology"
Kathleen Ebert-Zawasky and Gerald Abegg 125

"Verbal and Nonverbal Behaviors of "Experts" During
Computer-Based Problem Solving in Genetics"
Patricia E. Simmons and Judith Kinnear 126

Contributed Papers - Cognitive Test Development

"Cognitive Process Analysis of Test Questions in a
Computer-Managed College Biology Course Based on a
Learning Style Assessment"
Claudia Melear 128

"Describing Changes in Students' Cognitive Structure
by Using an Individual Difference Model in
Multidimensional Scaling"
Wolff-Michael Roth 129

"An Instrument to Measure Spatial-Symbolic Information
Processing Ability"
Donna F. Berlin and Arthur L. White 129

"Development of a Paper-And-Pencil Instrument to Elicit
Student Concepts Concerning the Earth as a Planet"
William E. Crews, Jr. 131

"Profiling Pre-Service Elementary Teachers' Knowledge
of Density Using Three Assessment Techniques"
Marianne B. Barnes, Lehman W. Barnes and
Clive Andriesse 132

"The Influence of Preservice Secondary Science
Teachers' Beliefs on Planning"
Hsiao-lin Tuan and Annette LaRussa 133

Posters - Teachers and Teaching

"Videotape Analysis of the Relationship Between Teachers'
Hands-On Teaching Effectiveness and Students' Gains in
Science Achievement"
Robert L. Hartshorn, J. Preston Prather and
Ramona Nelson 135

"Using Internship-Generated STS Curriculum Projects as a Focus for Facilitating Teacher Enhancement"
Carole P. Mitchener, Paul S. Markovits and Jerilynn Changar 136

"The Evaluation of a K-6 Science Inservice Program: Examining an Effective Delivery Mechanism"
Charles R. Barman and Jill D. Shedd 137

"Results of an Inservice Workshop to Promote Science-Technology-Society Instructional Orientations"
Lawrence C. Sharmann 138

"Self-Perceptions and Professional Development in Elementary School Science Teaching"
David L. Haury 139

"A Retrospective Evaluation of the Program to Improve Elementary Science"
Edward J. Zielinski and Bruce Smith 140

"The Computer Partnership: A Case Study of the Development of a School/Business Partnership"
Karen K. Lind 141

"Assessing Students' Conceptions in Biology Using Prediction Problems"
Derrick R. Lavoie 142

"An Evaluation of the Small Instructional Group in the Secondary Biology Classroom"
Steven R. Rogg 143

"The Effects of Hands-On, Minds-On Teaching Experiences on Attitudes of Pre-Service Elementary Teachers"
Jon E. Pedersen and Donald McCurdy 144

Symposium

"The Nature of "Exemplary" Science Teachers: Implications for Teacher Education"
Robert E. Yager, Barry Fraser, David Treagust, Avi Hofstein, Ronald J. Bonnstetter, Kenneth Tobin and James J. Gallagher 145

Contributed Papers - Cognitive Change

"A Case Study of Conceptual Teaching: Teaching the Necessity of Conservation Reasoning in Physical and Chemical Changes"
Joseph J. Hesse III and Charles W. Anderson 147

"Hump Effect as Observed During Problem-Solving"
Narendra Vaidya 147

"A Mathematical Model of Cognitive Development"
Shulamith G. Eckstein and Michal Shemesh 148

"An Evaluative Study of Level One Instructional Videodisc Materials Used in Science Classrooms"
Robert Sherwood, Ted Hasselbring and E. Jean Marsh 149

"A Logico-Structural, Worldview Analysis of the Interrelationship Between Science Interest, Gender, and Concept of Nature"
William Cobern, Jane Ellington and Daniel Schores 150

Contributed Papers - Prospective Teacher Development

"The Comparison of Cognitive Development, Science Process Skills, and Scientific Attitude of Preservice Teachers with Different Science Background"
Tien-Ying Lee 151

"Teacher Preparation: The Academic Development of Preservice Middle School Science Teachers"
Teresa M. Kokoski, Hsiao-Lin Tuan, Russell H. Yeany and Michael J. Padilla 151

"The Effects of a Project Learning Tree Workshop on Pre-Service Teachers' Attitudes Toward Teaching Environmental Education"
Dorothea E. Kunz and Patricia Farrell 152

Contributed Papers - Student Conceptions in Science

"Cell Division: Student Misconceptions and Instructional Implications"
Mike U. Smith 154

"Students' Conceptions of Basic Ideas of the Second Law of Thermodynamics"
Reinders Duit and Sofia Kesidou 154

"On the Instability of Misconceptions: How Students Form Their Concept of Isomerism"
Hans-Jurgen Schmidt 155

Contributed Papers - Student Knowledge and Structures

"Effects of Concept Mapping on Meaningful Learning and Achievement in Secondary Chemistry"
Jimmy Daniel Allen 156

"Manipulation of Logical Structure of Chemistry Problems and its Effects on Student Performance"
Mansoor Niaz and William R. Robinson 157

"The Relationship Between Students' Learning Strategies and the Change in Their Chemical Misunderstandings During a High School Chemistry Course"
Saouma BouJaoude 157

Symposium

"Multicultural Science Education: Definitions and Research Agendas for the 1990's and Beyond"
Mary M. Atwater, Joseph Riley, Lowell Bethel, Julia Clark and Steven Rakow 159

Panel

"Integrating the History and Nature of Science into Science Teaching"
James D. Ellis 160

Contributed Papers - Attitude and Affect

"Beliefs, Attitudes, and Intentions of Science Learners in Public, Private, and Home Schools"
Brian D. Ray 162

"Researching Balance Between Cognition and Affect in Science Teaching and Learning"
Richard Gunstone, John Baird, Chris Penna and Richard White 162

Contributed Papers - Conceptual Change

"Using Conceptual Change Research and Project 2061 to Improve Science Assessment Programs"
Charles W. Anderson, Mozell Lang and Elizabeth Stevens 164

"An Analysis of the Relationships of Formal Reasoning, Science Process Skills, Gender, and Instructional Treatment to Conceptual Shifts in Tenth Grade Biology Students"
Susan L. Westbrook, Laura N. Rogers and Edmund A. Marek 165

"Science as a Vehicle for Promoting Cognitive Development in High School Students"
Philip S. Adey 166

Contributed Papers - Prospective Teacher

"Misconceptions about the Moon Held by Preservice Teachers in Taiwan"
Meme Dai and William Capie 167

"The Science Preparation of Elementary Teachers"
Linda R. DeTure, Eileen Gregory and Brian Ramsey 168

"Science Teaching/Learning in New York City Secondary Schools - A Focus on Research Needed in Urban Communities"
Pamela Fraser-Abder, Andrew Apicos, Marlene Licciardello, Salvatore Maugeri, Maria Obregoro and Karina Sweeney 168

Contributed Papers - Gender and Science II

"Gender Differences in Science: Where They Start and Where They Go"
Dale Baker 170

"Weaving a Network of Early Support for Girls in Science: Empowering Elementary Teachers"
April L. Gardner, Teresa McDevitt and Mark Constas 171

"Gender Differences Research and Feminist Research: Prospects for the Future"
Nancy W. Brickhouse 171

Index 173

Symposium

ESTABLISHING TRAINING CENTERS FOR INSERVICE SCIENCE TEACHERS

James D. Ellis
Phil Goulding
Janet C. Powell
Michael R. Hannigan
Biological Sciences Curriculum Study
Colorado Springs, CO 80903

Cecilia Lenk
TERC
Cambridge, MA 02138

The poor implementation of innovative science curricula and teaching methods is a pervasive problem in science education. Few teachers currently use the science curriculum projects from the past three decades. Furthermore, one need only look at the list of papers presented at the 1989 meetings of the American Educational Research Association and the National Association for Reserach in Science Teaching to see that teacher education is receiving much attention from educational researchers.

In response to the educational crisis, the National Science Foundation (NSF) and the Department of Education (ED) have funded curriculum development and teacher enhancement projects that include an emphasis on teacher education and implementation. Consequently, a major problem confronting curriculum developers and publishers who abide by the NSF mandate is how to provide teacher training and implementation support to the multitude of science teachers throughout the nation. The traditional approach of publishers has been to provide a complimentary one- or two-day inservice workshop on the features of the textbook and supplementary materials and to provide no follow-up support beyond the initial workshop. To successfully implement a new program, however, teachers need intensive training coupled with long-term support (over two or more years).

One common solution to the problem of too many teachers and too few trainers is to use a trainer-of-trainers model to establish local and regional training centers, which in turn provide the training and, more importantly, the follow-up implementation support. Consequently, three federally funded projects are establishing training centers to help teachers throughout the nation implement new aproaches to science teaching.

The Biological Sciences Curriculum Study (BSCS), with support from NSF, is establishing training centers to implement the ENLIST Micros teacher training and implementation model. ENLIST Micros is a multiphased project to help teachers (K-12) improve their use of microcomputers in science instruction. Phase I developed a text, a set of four video programs, and a set of two disks of computer software to help teachers acquire the information and skills needed to use microcomputers in science instruction. Phase II developed a staff development and implementation model for helping teachers integrate educational computing into science instruction. Phase III, a 42-month project that began 1 February 1989, will establish 12 or more ENLIST Micros training centers throughout the nation.

The Biological Sciences Curriculum Study (BSCS), with support from NSF and a commercial publisher, also is developing and implementing a middle school science and technology program titled Science and Technology: Investigating Human Dimensions. Fifteen primary and secondary sites will field test the materials. Each site will establish a university/school liaison. Furthermore, BSCS, in collaboration with the commercial publisher, will develop a network of consultants to coordinate ninety tertiary field-test sites. Ten tertiary sites will be linked to each of nine secondary sites. BSCS will conduct training workshops for university personnel and publisher consultants; these personnel will then provide support and training to schools.

The Technical Education Research Centers (TERC), with support from ED, is developing an innovative curriculum and establishing training centers throughout the nation to implement the curriculum. The Star Schools project is developing nine units of instruction to promote original, student-initiated projects in secondary school science and mathematics. Telecommunications is a central feature of Star Schools. During June 1989, TERC conducted a trainer-of-trainers workshop for staff from more than 10 centers. TERC anticipates that once support from ED ceases, TERC will be able to distribute, at low cost, the Star Schools curriculum and provide training and implementation support to schools throughout the nation through its network of Star Schools training centers.

Panel

EXPLORATION OF OPPORTUNITIES IN INFORMAL SETTINGS FOR SYNTHESIS OF TEACHER PREPARATION, EXHIBIT EVALUATION, AND RESEARCH ABOUT LEARNING IN SCIENCE

Charles R. Ault, Jr.
Lewis and Clark College
Portland, OR 97219

Michael R. Cohen
Linda Furuness
Indiana University
Indianapolis, IN 46223

Deborah L. Perry
Monroe, WA 98272

Piyush Swami
University of Cincinnati
Cincinnati, OH 45221-0002

In 1983 A.M. Lucas gently reminded science educators "that most people must learn for most of their lives" outside of school. Furthermore, he posed the provocative challenge of judging school courses on "how well they provide a framework for future informal learning." Informal learning in science museums and zoos is one obvious way people encounter messages with potential educational value outside of school, and, although such environments serve many recreational, economic, social, and political functions within a community, much of their success is predicated on the assumption that visitors do learn from informal experiences and that those who design encounters with exhibits can influence this learning in desirable ways. Looming before such attempts is acknowledgement that despite the clear superiority of informal settings over schools for introducing large numbers of people to interesting, provocative, and valued objects (the "things" of science, as discussed by Falk in 1986), science museums "may very likely be ineffectual" for conveying "abstract and complicated" information.

No one can state with certainty where the limits of informal learning's ability to enhance scientific understanding lie, for the environment, by definition, eschews formal assessment. Moreover, the factors influencing science learning in informal settings range from the presumably (but not necessarily) straightforward task of describing the attributes of museum exhibits, for example, to the very difficult problems of determining what knowledge and intentions people bring to informal science centers, how social interaction and cultural background influence the manner in which they approach exhibits, whether or not any change in visitor understanding or attitude has occurred as a consequence of attending to an exhibit, and in what ways formal and informal learning may prove mutually reinforcing. While these concerns are not new, science educators have recently uncovered intriguing opportunities in informal settings for both the application and

conduct of research about "everyday" conceptions of natural phenomena (e.g., motion, light) commonly held by people from childhood through adulthood. The study of visitor interaction with exhibits and each other -- often by means of interviews -- can reveal whether science learning in informal settings influences such conceptions as well as provides insights into their structure. This research often not only raises questions about assumptions regarding science learning followed by educators and exhibit planners in either formal or informal settings, but also provides effective formative or "front end" evaluation of specific exhibits the museum community has newly designed.

A fruitful arena of mutually beneficial inquiry, such investigation also has value to a third audience: teachers. Whether as part of initial preparation or a program of enhancement, teachers can respond directly to the challenges of formative evaluation of science exhibits in informal settings using both observational and interviewing techniques and thereby meaningfully participate in the conduct of qualitative educational research.

This panel has assembled to: (1) share a variety of approaches to formative evaluation of science exhibits in informal settings (zoos and museums), and (2) explore the value of cooperation between centers of informal learning and educational researchers, with special attention to the opportunity to facilitate growth in teachers' conceptions of learning and knowing science. Presenters will address the need for theoretical models in the conduct of such work, types and methods of data-gathering, and examples of present and forthcoming programs involving teacher education, museum learning, and educational research.

A HIERARCHICAL-NETWORK MODEL OF COGNITIVE STRUCTURE: APPLICATIONS TO SCIENCE CONTENT ANALYSES

O. Roger Anderson
Columbia University: Teachers College
New York, NY 10027

Current cognitive theories assume that information can be efficiently stored hierarchically in memory and that multiple connections among informations units, forming a logically ordered network, enhance stability and efficiency of recall. Neurophysiological and neuropsychological evidence indicates that major central nervous system centers are hierarchically organized, and integrated by cross-lateral innervation, thus lending further credence to the hierarchical-network model of the cognitive theorists. A hierarchical-network model of information organization is presented and demonstrated using text narrative from a standard secondary school biology textbook. The rationale for the model is based on constructs from cognitive science and information processing theory. For written narrative, the paragraph is the basic unit of analysis. Each paragraph is represented as a tripartite hierarchy by identifying (1) the major theme idea of the paragraph (highest level of the hierarchy), (2) a subtheme for the paragraph (intermediate level), and (3) a minor theme (lowest level of the hierarchy). This is done for each paragraph in the communication to be analyzed. These data are entered in a matrix (columns = paragraphs and rows = hierarchical levels). The proportional occurrence of each theme in the total matrix is computed and entered in the cell in place of the theme code. These proportions are used to compute weighted indices of structure for each level of the hierarchy across paragraphs. The computing algorithm for the first level is based on the idea that there should be maximum diversity of content across the paragraphs (entropy of information theorists) but close linkage of these major theme ideas downward to lower levels of the hierarchy (connectivity). Further weighted connectivity indices are computed for each sublevel of the hierarchy and entered in the matrix. Column totals of these indices represent the structural contribution of each paragraph to the total communication. A mean value of the column totals provides an overall estimate of the structure in the cross-linked set of hierarchies. This method can be used as a content-analysis system for science texts or as a method to elucidate learner's schemata by analyzing their written products after a learning experience.

INTEGRATION OF DOMAIN SPECIFIC KNOWLEDGE AND GENERAL STRATEGIES IN SOLVING NOVEL PROBLEMS IN THE SCHOOL SCIENCE LABORATORY

Pinchas Tamir
Hebrew University of Jerusalem
Jerusalem, Israel 91904

The study describes an example of a state-wide high school biology curriculum which has succeeded in teaching high level problem solving and inquiry skills by generality and context specificity in instruction. The focus is on the development and implementation of inquiry oriented investigations which have become an integral component of the Israeli BSCS Adaptation Program.

Close to one hundred investigations were originally designed as test problems for the biology matriculation examinations in Israel. Once they have served as an examination, the problems became part of the laboratory manual of the course in grades 10, 11, and 12. Since each of these investigation problems require students to exercise inquiry skills such as formulating hypotheses, designing controlled experiments, collecting and interpreting data, etc., students have ample opportunities to become proficient in these skills and apply them in different contexts and a variety of content areas.

On the average, results of inquiry oriented laboratory tests reveal a high level of achievement. Girls perform better than boys and Jewish students perform better than do Arab students. Vast differences exist between strong and weak schools, which reflect different instructional routines and different opportunities to learn offered by different schools. The relative success of the biology curriculum in Israel compared with that reported regarding inquiry in the U.S. is explained by the way the educational system in Israel has mobilised its resources, most notably its matriculation examinations to support the development of cognitive problem solving skills of the biology students.

HYPOTHETICO-DEDUCTIVE REASONING AND CONCEPT ACQUISITION: A TEST OF THE CONSTRUCTIVIST HYPOTHESIS

Anton E. Lawson
Arizona State University
Tempe, AZ 85287

This study tested the general constructivist hypothesis that the acquisition of domain-specific conceptual knowledge (declarative knowledge) requires use of general procedural or "operative" knowledge. More specifically it was hypothesized that use of a general pattern of hypothetico-deductive reasoning is necessary for the acquisition of novel domain-specific concepts. To test this hypothesis 314 high school biology

and chemistry students were first tested to determine whether or not they were skilled in the use of hypothetico-deductive reasoning. Based on this test, students were classified as reflective, transitional or intuitive thinkers. All students were then presented with a series of four concept acquisition tasks. It was predicted that reflective (hypothetico-deductive) thinkers would successfully acquire the concepts while intuitive (empirico-inductive) thinkers would not. Transitional thinkers were expected to be partially successful. These predictions were confirmed as hypothetico-deductive reasoning skill (developmental level), but not age, was highly correlated with performance on the concept acquisition tasks (X^2=71.14, p<.00001). This result was interpreted to be supportive of the constructivist hypothesis and contradictory to the alternative hypothesis that students use prior domain-specific knowledge to acquire novel concepts instead of general cognitive operations.

RELATIONSHIP BETWEEN SUBJECT MATTER STRUCTURE AND SOCIAL CLASSROOM INTERACTIONS IN HIGH SCHOOL PHYSICS

Armando Contreras
Universidad de Los Andes
Trujillo, Edo Trujillo-Venezuela 3102

A current trend in science education research is the study of how subject matter is organized in real life for meaning, as an effort to understand the content of teaching and its effect. This research paper describes the case study of an experienced teacher as he engaged in the teaching of Newton's second law (F=ma) following the PSSC curriculum with a class of twelfth-grade students in a middle-class school located in the midwest (U.S.A). The study substantially focuses on the nature of the interaction between the subject matter structure and the simultaneous social task environment being enacted as the topic on Newton's second law is sequentially organized in real time. The research study followed standard ethnographic methods for data gathering such as: videotaping, fieldnotes, interviews, and document gathering. The process of data gathering lasted 6 months, time during which more than 100 observations were conducted and 11 videotaping sessions of 50 minutes each were carried out. Also, lab reports, tests, handouts were carefully filed because they contained important information related to the organization of subject matter.

An interpretive framework based on ethnography of communication and sociolinguistics was implemented to describe how the logical relationships embedded in the teaching of Newton's second law were manifested in the social context under study. In this sense, the researcher conducted a detailed discourse analysis in which the participants' verbalizations and their actions during those verbalizations were made explicit for the process of data analysis. The analysis also allowed for the inclusion of previously enacted topics which somehow were related to the development of the topic under study: i.e., Newton's second law. Emphasis was placed on the subject matter information content, its logical sequence, as well as on the physical materials through which tasks were manifested and completed.

The study provides empirical support for the assertion that the sequential organization of subject matter in high school physics is simultaneously integrated into the social task environment of the classroom where that subject matter is enacted. The study also confirms the assertion that science lessons are not pre-set entities but that they are characterized by a dynamic process which depends on the relationship between the academic task structure and the social task environment. The research offers some new challenging questions for science education research. First of all, it presents a theoretical framework for learning about how subject matter is actually constructed in real life. Descriptions of this type are pertinent if we are to empirically study the effect of any science curricula upon individual student learning. Secondly, descriptions on subject matter enactment are also important for teachers themselves as they can reflect upon their own content of teaching and their social environment as that content is being delivered.

CURRICULUM AND INSTRUCTIONAL PRACTICE IN THE PHYSICS, CHEMISTRY, BIOLOGY AND GENERAL SCIENCE CLASSROOMS

Wilmad A.J.M. Kuiper
Annita Alting
University of Twente
Enschede, The Netherlands

The purpose of the Dutch Science Subjects study was to investigate:
- the actual instructional practice in the subjects physics, chemistry, biology and general science in all forms of lower secondary education in the Netherlands;
- similarities and differences between the several forms of lower secondary education in the actual instructional practice in these subjects;

The study was undertaken in the context of the intended reorganization of lower secondary education and was embedded in research efforts aimed at identifying factors which are linked with productivity in the domain of science education. It focused on curriculum materials and teacher behaviors.

Information was gathered in breadth and in depth. The research strategy consisted of three parts: a preliminary investigation, a survey, and nine case studies. The paper describes the design, the instrument and the results of the survey. The survey data were collected in the spring of 1989 by means of a precoded written questionnaire which was submitted to a stratified random sample of 1187 teachers, spread over the subjects physics, chemistry, biology, and general science. The response rate was 72.3% (856 questionnaires). Data were collected on: the kind of textbook(s) and other materials teachers use, the way they use these documents, and motives for choosing a textbook; the science subjects instruction topics; the science subject instructional process (the relation between the content of science subject instruction and the world outside the classroom); contacts with colleagues; laboratory and field work; lesson preparation; homework; evaluation of student achievement; need for educational facilities and equipment; use of the computer; teacher characteristics as age, gender, qualifications, inservice training and membership of a professional association. All survey data refer to the school year 1988-1989.

Some of the results are:
- during lesson preparation and instruction teachers are heavily reliant on textbooks;
- integration of science subjects topics hardly occurs;
- as grade level rises teachers are less inclined to treat topics related to the world outside the classroom and more attention is paid to subject-specific concepts;
- whole-class interactive activities (the teacher presenting content in a lecture mode with questions being asked, the teacher demonstrating an experiment) are predominant;
- the lesson preparation is generally directed to treatment of subject-matter (topics, sequence, explanation), to learning activities and also, but to a lesser extent, to objectives;
- homework, tests and examinations have a high status;
- during their lessons less than 10% of the teachers made use of the computer.

SCIENCE INSTRUCTION FOR THE MILDLY HANDICAPPED: DIRECT INSTRUCTION VERSUS DISCOVERY TEACHING

John R. Staver
Kansas State University
Manhattan, KS 66506

Mary Bay
Tanis Bryan
James B. Hale
University of Illinois at Chicago
Chicago, IL 60680

The purpose of this study was to determine the relative effectiveness of two instructional techniques for students in mainstreamed science classes. Mildly handicapped (BD and LD) and nonhandicapped students were assigned at random to one of two conditions. One condition utilized principles of direct instruction, including teacher demonstrations, teacher-directed questioning, teacher-directed guided practice, and frequent review. The other condition used principles of discovery teaching, including gathering data, generating and implementing solutions, and observing the consequences. The science lessons involved: (1) The notion of displacement as it relates to floating/sinking of objects; (2) the concept of variable as it pertains to the thickness of a raft as a predictor of the amount of cargo that can be supported; (3) the process of controlling variables during experimentation; and (4) the relationship between controlled variable experimentation and prediction. The students participated in small instructional groups that met daily for four lessons. Results show that students in both groups learned equally well as measured by an immediate posttest. However, students in the discovery teaching condition outperformed their direct teaching counterparts on a retention test administered two weeks after the posttest. A generalization test, also administered two weeks after the posttest, showed that LD students in the discovery teaching condition outperformed their LD counterparts in the direct instruction condition.

SURVEY OF FACTORS THAT STRESS SCIENCE TEACHERS AND AN EXAMINATION OF COPING STRATEGIES

Peter Okebukola
Lagos State University
Lagos, Nigeria

Olugbemiro J. Jegede
Ahmadu Bello University
Zaria, Nigeria

Science teacher stress is a topic that has attracted only a few studies in recent years. Since teaching conditions are not getting any better, it is becoming increasingly evident that science teachers will be exposed to a great deal more stress in the years to come. What are those conditions or situations that stress science teachers? How can the teachers cope with these stressors so that productivity does not take a dip? These are important questions that merit attention at this time.

Stress, a condition of mental and physical exertion brought about as a result of harassing events or dissatisfying elements in the environment, can lead to mental and physical ill-health. This in turn can lead to a lowering of on-the-job performance - a situation that cannot be tolerated in these days when ways are being sought to improve the quality of teaching in our schools.

When the scores of all the 206 respondents to the 40-item Science Teacher Stress Inventory for each possible stressor were pooled and ranked, the top five stressors were found in descending order to be: (1) Difficulty in obtaining equipment and materials for teaching science effectively; (2) Having to cope with teaching traditionally difficult topics in my subject; (3) Inability to complete the syllabus before external examinations are due to start; (4) Having to teach subjects like General Science or Integrated Science that one is not trained for; and (5) Having to cope with the demands of new curricula.

Among the strategies teachers adopt for coping with stressful conditions are: More frequent undertaking of field trips to release class tension; sharing of ideas and laboratory equipment with colleagues; positive thinking about the important role of the science teacher in nation building; relaxation and leisure; and more determined attempts at improvisation.

As we approach the third millenium, the society gets more complex and greater demands are made on the science teacher. It is auspicious at this time to keep track of those factors that can mentally and physically exhaust the science teacher by virtue of being engaged in the science teaching profession. This is why this line of inquiry should be on the research agenda world-wide. It is in fact apt to make science teachers aware of how to cope with these stressors through counselling programmes. With this, the science teacher can keep his/her head up high in the anticipated stressful times of 2000 A.D. and beyond.

TEACHER KNOWLEDGE AND THE LANGUAGE OF SCIENCE TEACHING

William S. Carlsen
Cornell University
Ithaca, NY 14853

This paper describes the effects of science teacher subject-matter knowledge on classroom discourse at the level of individual utterances. It details one of three parallel analyses conducted in a year-long study of language in the classroom of four new biology teachers. The conceptual framework of the study predicts that, when teaching unfamiliar subject-matter, teachers will utilize a variety of discourse strategies to constrain student talk to a narrowly circumscribed topic domain. This paper includes the results of an utterance-by-utterance analysis of teacher and student talk in a 32-lesson sample of science instruction. Data are broken down by classroom activity for a number of measures, including mean duration of utterances, domination of the speaking floor by the teacher, frequency of teacher questioning, cognitive level of teacher questions, and student verbal participation. When teaching unfamiliar topics, the four teachers in this study tended to: talk more often and for longer periods of time, ask questions frequently, and rely heavily on low cognitive-level questions. Students were less likely to speak and spoke for shorter periods of time, even when responses to teacher questions were included in the analysis. The implications of these findings include a suggestion that teacher knowledge may be an important unconsidered variable in research on the cognitive level of questions and teacher wait-time.

TEACHER PERSONAL PRACTICAL THEORIES AND THEIR INFLUENCE UPON TEACHER CURRICULAR AND INSTRUCTIONAL ACTIONS: A CASE STUDY OF A SECONDARY SCIENCE TEACHER

Catherine G. Yeotis
Wichita State University
Wichita, KS 67208-1595

Jeffrey W. Cornett
University of Central Florida
Orlando, FL 32816-0250

This paper describes the procedures and the findings from a case study conducted on the planning and classroom actions of a secondary science teacher. The primary objective of this study was to investigate the relationship between the teacher's personal practical theories and her conception of the curriculum. It was also the investigators' objective to determine the teacher's view of her role in the development of the science curriculum. The investigation followed the methodological guidelines of the naturalistic or qualitative research paradigm as discussed by Lincoln and Guba in their book Naturalistic Inquiry.

The trustworthiness of the data was verified using several established methods. The findings were triangulated, first by the teacher thinking researcher, then by the secondary science teacher, and finally by a science methods expert who had also observed the teacher during the research period.

A description, analysis, and interpretation of the teacher's curricular practice will be presented in the paper. Through the analysis of the data, several findings emerged. These included the following:

1) seven personal practical theories influence the teacher's conception of the curriculum, curriculum development, and instruction;

2) the theories were interactive and dependent upon a variety of external influences and also the teacher's perception of human, material, and temporal classroom resources;

3) the dominant personal practical theory was related to the discipline and control of the students, and was manifested in the teacher's practice through a highly structured approach to the curriculum;

4) the teacher participant had no metaview of these theories or their interaction prior to this investigation;

5) the teacher did not view herself as having an impact on curriculum development, even though she significantly determined what students had the opportunity to learn;

6) the teacher's theories were observable in her practice by both a teacher thinking researcher and a science methods expert unfamiliar with this type of inquiry and untrained in naturalistic methods.

THE USE OF CONCEPT MAPS IN EXAMINING STUDENTS' CONCEPTIONS AND STRUCTURE OF KNOWLEDGE IN SCIENCE

Josephine D. Wallace
East Carolina University
Greenville, North Carolina

Joel J. Mintzes
University of North Carolina at Wilmington
Wilmington, NC 28403-3297

This study examined the usefulness of the concept mapping strategy for assessing conceptual change in college science students. Specifically, the study focused on the extent to which achievement gains resulting from short segments of computer-assisted instruction reflect changes in the content and structure of knowledge as revealed in concept maps.

Ninety-one (91) students who enrolled in an elementary science methods course were randomly assigned to one of two treatment groups. Subjects in both groups were administered a multiple choice/free response inventory (alpha=.76) which assayed their knowledge of "Life Zones in the Ocean." Subsequently, each subject was provided a set of nine concept labels (e.g., continental shelf, intertidal zone, phytoplankton) and asked to develp a concept map on life zones. Subjects in the experimental group then engaged in a 45 minute interactive program which introduced basic concepts of marine life zones. Those in the control group received an equivalent exposure to an unrelated topic. Upon completing the instructional sequence, subjects were again administered the "Life Zones" inventory and developed a post-instruction concept map on marine life zones.

The data were analyzed by analysis of variance employing a split-plot factorial design. As expected, small but significant differences ($F_{1,89}$ = 5.47; $p<.05$) favoring the experimental group were detected on the "Life Zones" inventory. The focus then shifted to the question at hand: do these achievement gains reflect changes in cognitive structure as revealed in the concept maps?

Using a modified form of Novak's scoring technique, significant and substantial differences were found between groups in every scoring category. Concept maps of the experimental group revealed a greater number of: relationships ($F_{1,89}$ = 30.34; $p<.001$), levels of hierarchy ($F_{1,89}$ = 26.68; $p<.001$), branchings ($F_{1,89}$ = 29.82; $p<.001$), cross-links ($F_{1,89}$ = 12.30; $p<.001$), and general-to-specific propositions ($F_{1,89}$ = 4.28; $p<.05$).

In a "post hoc" validation, ten students in the experimental group were interviewed; five whose mapping scores were the highest ("experts") and five whose mapping scores were the lowest ("novices"). Interview responses were transcribed and then analyzed for "critical concepts" and "critical propositions" (those deemed central to an understanding of the program by a panel of outside judges). Analysis revealed substantial differences favoring the "expert" subjects.

These results suggest that the concept mapping strategy is a remarkably sensitive mechanism for documenting conceptual change and should be considered an important adjunct to traditional evaluation tools.

AN ANALYSIS OF STUDENT INTERACTIONS AND BEHAVIORS DURING PROBLEM SOLVING WITHIN THE SSCS INSTRUCTIONAL MODEL UTILIZING PATH ANALYSIS

Daniel P. Shepardson
Edward L. Pizzini
The University of Iowa
Iowa City, IA 52242

The classroom dynamics (class setting, problem solving phase, student interactions, and student behaviors) of the SSCS problem solving model of instruction were analyzed using path analysis. The proposed causal model was trimmed based on path coefficients with levels of significance greater than p=0.05. The path coefficients suggest that the problem solving phase has greater (direct) effect on student behavior, while student--interactions have little direct correlation to student behaviors. Thus, the phase of problem solving influences student behaviors, as students respond to the context of solving the problem. The data collection phase tends to directly influence student attending, soliciting and giving behavior; while research design directly affects student following behavior, and the evaluation phase influences student soliciting behavior. Problem finding did not directly influence any specific student behavior. At the same time, student interactions are a function of the class setting with small class setting positively influencing student--student interactions and negatively affecting student--teacher interactions.

STUDENTS' INTUITIVE IDEAS ABOUT "WATER IN THE ATMOSPHERE": A CROSS AGE STUDY

Chan-Jong Kim
James P. Barufaldi
The University of Texas at Austin
Austin, TX 78712

Students bring intuitive ideas into science classrooms which are often in conflict with commonly held scientific views. Such intuitive ideas have crucial effects on students' perceptions and their processing of new information and also interfere with science learning.

During the last decade many research studies in science education have attempted to identify intuitive ideas and their characteristics; however, only a small number of concepts in earth science has been studied in terms of students' intuitive ideas. In addition, few researchers have investigated the patterns of change of students' intuitive ideas across ability levels.

The purpose of the study is to identify and describe various students' intuitive ideas about one important earth science concept, "water in the atmosphere" and the patterns of change in students' intuitive ideas across grade and ability levels.

The results from a preliminary study identified many intuitive ideas about the physical and chemical properties of the earth. The concept, "water in the atmosphere," was selected for an in-depth study. The content analysis of the concept resulted in the identification of seven sub-concepts (water vapor, humidity, evaporation, condensation, sublimation 1 and 2, and dew point). An interview guide was developed, pilot tested, and revised using subjects from the elementary school to college level.

A total of 36 subjects (nine subjects per grade: 5th-, 8th-, 11th-grade, and college) was selected from the Central Texas area. Each of the grade levels (except college level) included three above-average, three average, and three below-average subjects. Clinical interviews were conducted using the interview guide and were audio-tape recorded, transcribed, and analyzed.

The results of the study identified three to seven notions for the sub-concepts. The notions were arranged on a less-sophisticated (phenomenal/mechanical) to more-sophisticated (abstract/molecular) continuum. Two patterns of change of notions were identified: progressive differentiation (water vapor, humidity, and evaporation) and discontinuous change (condensation, sublimation 1 and 2, and dew point). The higher the grade level, the more sophisticated the notions; the higher the ability level, the more sophisticated the notions. Relevant anchoring ideas were differentiated into compatible and alternative relevant anchoring ideas. "Restructuring series," the order of restructuring of the sub-concepts, was defined and identified: water vapor-humidity and dew point-condensation-evaporation-sublimation 1 and 2. The subjects' responses about evaporated water were similar to those characterized by an Aristotelian view. The subjects already held a firm understanding of water cycle. The most important and influential concept to the restructuring of the concept, water in the atmosphere, is "the capacity of air to hold water vapor depends on the temperature of the air."

It was found that the availability of alternative or compatible relevant anchoring ideas, the degree of differentiation of the existing relevant ideas, and linkages among the relevant ideas in the cognitive structure are the crucial factors of cognitive structure for the restructuring of existing ideas. Students' intuitive ideas and the influence of such ideas on science learning should be incorporated into science instruction, the design of science textbooks, and science teacher education programs.

STUDENTS' PERCEPTIONS OF THE NATURE OF SCIENCE: ASSESSMENT, DEVELOPMENT, AND SOURCES OF CHANGE

Norman G. Lederman
Oregon State University
Corvallis, OR 97331

Research concerned with the nature of science as an instructional outcome has focused primarily upon students' understanding of the tentative and revisionary aspects of scientific knowledge. Interestingly, researchers have been content to ask students "what they believe," but have not bothered to ask students about the sources of their beliefs or the experiences which have altered these beliefs. The purpose of this investigation was to: (1) assess students' beliefs about the tentativeness of scientific knowledge and (2) identify the various sources of students' beliefs as well as those factors which have altered these beliefs.

A total of 69 high school students spanning grades 9-12 and all sciences constituted the sample for this study. An open-ended questionnaire designed to assess students' beliefs about the tentativeness of science was administered at the beginning of the fall term and again at the end of the school year. A stratified random sample of 20 students was selected for "follow-up" videotaped interviews. These interviews were used to further clarify students' beliefs and the sources of these beliefs.

Questionnaire responses were qualitatively categorized based on their adherence to a tentative or absolutist view of scientific knowledge. Students' responses tended to align slightly more closely with the tentative viewpoint. However, laws were distinguished from theories on the grounds that laws have been proven.

The "follow-up" interviews indicated, without exception, that the students correctly interpreted the meaning of each questionnaire item. It became clear during the interviews that the students' use of the word "prove" (while discriminating between laws and theories on the questionnaire) was intended to be synonymous with supportive evidence as opposed to the absolutist interpretation inferred by the researcher. This discrepancy between the meaning of the students' written language and the researcher's interpretation has significant implications for the adequacy of paper and pencil measures in the assessment of students' beliefs and attitudes.

Qualitative analysis of interview transcripts yielded a variety of intriguing insights. In addition to self reflection and numerous examples, a substantial knowledge base was identified as a prerequisite to an understanding of the tentativeness of scientific knowledge. This view contradicts current instructional prescriptions which advocate that an understanding of the nature of science must precede any "true" understanding of subject matter. In addition, although the presentation of numerous examples was cited as an influential factor, virtually none of the students could provide such examples. Thus, the inability to recall specific examples did not inhibit the students' ability to understand the "big picture."

Perhaps the most intriguing findings of this investigation relate to the assumed benefits of curricula which emphasize S-T-S interactions. Without exception, students indicated that decisions affecting their daily lives would not be changed as a result of increased personal scientific knowledge. Clearly, the assumed benefits of scientific literacy must be carefully reconsidered within the context of the multitude of external and internal factors which affect one's personal decisions and actions.

Symposium

CHARTING NEW DIRECTIONS FOR SCIENCE EDUCATION IN THE MIDDLE GRADES

Paul J. Kuerbis
Rodger W. Bybee
Biological Sciences Curriculum Study
Colorado Springs, CO 80903

Audrey B. Champagne
American Association for the Advancement of Science
Washington, DC 20005

Michael Padilla
University of Georgia
Athens, GA 30602

Educational decision makers are faced with increasing pressure to improve the quality of science education, yet little practical guidance exists for educational policy makers and practitioners.

Recently, US Department of Education provided three years of funding for the National Center for Improving Science Education, a partnership between the NETWORK, Inc. of Andover, Massachusetts and the Biological Sciences Curriculum Study (BCSC) of Colorado Springs. The National Center's mission is to promote change in state and local policies and practices in science curriculum, assessment, and teacher development and support. The Center uses study panels of scientists, science educators and other experts to synthesize and translate the findings, recommendations, and perspectives embodied in recent and forthcoming studies into practical resources for policy makers and practitioners. During its second year, the Center exmined science education in the middle grades. This symposium is focused on the results of that work.

The symposium set out the findings on the present state of science education in the middle grades and made recommendations for how schools can bring about improvements. Three papers were presented based on the work of the National Center for Improving Science Education. The papers dealt with the following aspects of science education in the middle grades: curriculum and instruction, teacher development and support, and assessment of student learning. The purpose of the symposium was to put before the research and education communities the results of the Center's synthesis of research and practice and directions for moving forward from "what is" to "what ought to be" as specified by various commissions and experts in science and science education. The papers also reported on some feasibility studies being conducted by the Center relevant to implementing some of the suggested improvements.

The curriculum and instruction paper outlined a conception of science and technology that guided the development of a proposed curriculum framework based on nine organizing principles of scientific and technologic knowledge. It also presented a proposed instructional framework based current knowledge of how early adolescent students learn and of effec

classroom practices. The teacher development and support paper dealt with four major issues: teacher quality, teacher preparation, professional development and the role of a school's organizational context. The paper on assessment described how assessment can be used in the classroom and in the school to help improve science education. Four assessment issues were considered: the difficulty of assessing what we value most in student learning of science, the valid and invalid uses of assessment, broadening what counts as evidence in assessment, and assessing the quality of a school's science program. The papers also reported on several feasibility studies conducted by the Center relevant to implementing some of the suggested recommendations for improvement.

Bridging the gap between research, practice, and policy, the Center is committed to fostering cooperation and collaboration among organizations, institutions, and individuals concerned with improvement of science education. The NARST symposium served as a forum for presenting and critiquing the Center's work, an important step in that process.

Paper Set

THE USE OF MICROCOMPUTERS TO AID IN TEACHING GRAPHICS: ANALYSIS, SOFTWARE DESIGN AND STUDENT RESPONSE ANALYSIS

David Jackson
Carl F. Berger
The University of Michigan
Ann Arbor, MI 48109-1259

Billie Edwards
The Detroit Public Schools
Detroit, MI 48200

Research on the effectiveness of commercially available graphing application software to teach students about principles of graphical data analysis indicates critical design modifications are needed. A customized graphing program designed for use by high school students was constructed. An experiment designed to investigate the optimal balance, between flexibility and feedback in the design of such software was carried out and relationships of the design principles in the graphing program to general ideas in the philosophy of science education and of the design of computer artifacts are reported.

Graphs are one of the primary means of communication in the practice of science, and the importance of graphing skills has long been appreciated by science educators, but in a curiously limited way. Students are customarily taught, and are expected to practice, the mechanics of plotting graphs when given a table of information, but the time- and labor-intensive nature of the process interferes with student thinking. The use of a microcomputer can relieve the drudgery of the mechanics of plotting graphs, leading students to think about higher level graphing skills, and allow teachers to teach the higher-order thinking skills needed for intelligent and purposeful analysis. Building on the demonstrated success of microcomputer-based labs in helping science students to understand line graphs representing phenomena of motion, we generalized the use of computer-assisted graphical data analysis to involve students with relatively weak math and science backgrounds in using several kinds of graphs to solve problems in several different domains. Extensive observations and unstructured interviews with students in the process of solving problems, led to general principles of effective teaching about graphs in relation to real classroom teaching.

Research on problem solving has traditionally been restricted to studies of a very small and often unrepresentative sample of students, typically conducted in a controlled laboratory environment. The appropriate application of microcomputers has the potential to circumvent the artificial restrictions on research imposed by the time- and labor-intensive nature of traditional methods, thus providing for greater generalization of results to educational practice and possibly generating insights into problem-solving processes which emerge only at a macroscopic level. We carried out an investigation of the potential of computeriz-

data gathering and analysis based on sequence analysis in the natural sciences to open up research on problem solving to studies involving a very large sample of students, representative of a population of great interest, in a more typical classroom setting.

42

THE INFLUENCE OF TEACHERS' PERSONAL EPISTEMOLOGIES, BELIEFS, AND ROLE METAPHORS ON ASSESSMENT PRACTICES

Carol Briscoe
Anthony G. Lorsbach
Kenneth Tobin
Sarah L. Ulerick
Florida State University
Tallahassee, FL 32306-3032

This interpretive study of the use of alternative (i.e., to paper and pencil multiple-choice items) methods to assess student learning set out to investigate the factors which influence the validity of assessment tasks and those that determined how teachers assessed student learning. An assumption of this study was that the validity of an assessment task in a hands-on and minds-on science program was dependent on whether the tasks allowed students to demonstrate their knowledge in the way they had constructed it. Learning is recognized as a multi-modal activity; therefore, when students are asked to show what has been learned they should be provided with opportunities to represent what they know which are not constrained to selected contexts and limited response choices. Consequently, we were concerned with the extent to which teachers could incorporate alternative practices into their middle and high school science curriculum. The focus questions which emerged during the study centered on the influences that teachers' personal epistemologies, beliefs, and role metaphors had on the type and validity of assessment practices they used to evaluate students' knowledge. Interpretive research methodology was used to investigate the practices of three middle school teachers and two high school teachers from two urban schools. A research team of four (two of them were teachers in the study) designed the study, collected, analyzed and interpreted the findings of the study. Validity of the research findings was established from the triangulation of classroom observations, interviews of students and teachers, and documents produced by teachers and students.

The results of this study clearly indicated that teachers did not embrace alternative assessment tasks and use them in the manner intended. Rather, they adapted assessments to fit their personal epistemologies and beliefs about science, how students learn science, and their teaching roles. Teachers who held views of the nature of science and epistemologies consistent with positivist philosophy were inclined to use an assessment to measure the extent to which students were able to memorize facts and algorithms and use them in explaining natural phenomena. In contrast, teachers who regarded science as a process of finding tentative answers to questions were more likely to use alternative assessment tasks to ascertain whether students can participate in the process of finding tentative answers to problems. It was apparent that teachers made sense of assessment through the use of metaphors and associated beliefs sets and that changes in classroom assessment practices could be effected if teachers changed the metaphors used to conceptualize assessment and the

associated beliefs. These findings suggest that teachers will have to be assisted to change their personal epistemologies and beliefs before it can be expected that alternative assessment tasks will be used appropriately in science classrooms.

The results of this study have implications for the development of statewide assessment practices. As strategies are developed for creating statewide assessment tasks, there should be strong efforts to identify and utilize resources who not only have experience with science and teaching science, but those who have beliefs and epistemologies that are commensurate with the types of assessment tasks needed to provide valid measures of student learning. Policy makers who want to use assessment to "drive" the curriculum should exercise caution. This study suggests that most teachers will not use alternative assessment techniques in the manner intended. This subversion of intent could create problems if states were to adopt a policy of teachers using alternative assessment techniques and including alternative techniques in statewide assessment measures.

TEACHER PERCEPTIONS AND OPINIONS CONCERNING THE IMPLEMENTATION OF AN INQUIRY-ORIENTED SECONDARY BIOLOGY COURSE

David F. Treagust
Curtin University of Technology
Perth, Western Australia 6001

Ian Sydney-Smith
All Saints College
Perth, Western Australia 6155

Since its introduction to Australian secondary schools in the mid 1960's, the Web of Life, an adaptation of the green version of the Biological Sciences Curriculum Study, has gained a virtual monopoly in biology classrooms. Web of Life is taught as a two-year course in grades 11 and 12. During the 20 years that the Web of Life has been used in Australian biology classrooms, much has happened to the upper secondary school student population. When the Web of Life course was first introduced, retention rates of students into grades 11 and 12 from grade 10 was approximately 30%, while today this figure is almost 80%. This increase in retention rate has brought with it a greater diversity of student interests, academic abilities, attitudes, and vocational aspirations. These factors have generated some formal evaluation and much informal debate among biology teachers regarding the appropriateness of the present course for the student population.

The study sought to investigate this debate in an empirical manner by gauging the degree of satisfaction - dissatisfaction of the Web of Life course as indicated by a group of experienced biology teachers. The paper describes the development of a questionnaire designed to investigate biology teachers' perceptions and opinions about the implementation of a inquiry-oriented curriculum; reports on the findings of this questionnaire administered to a sample of experienced biology teachers; and recommends how appropriate inquiry-oriented biology courses can be best taught to upper secondary grade students.

Nine categories, comprising 50 items, were identified to be incorporated in the data collecting instrument - Teachers' Perception and Opinion Questionnaire. The format employed in the questionnaire was to use a two-part item, where the first part was designed to collect information concerning teachers' perceptions and the second part sought information on teachers' opinions. Subsequently, by tallying the number of response patterns for each item, it was possible to determine the degree of satisfaction/dissatisfaction of the sample of 80 experienced biology teachers who responded to the questionnaire.

From the questionnaire data it can be inferred that there is strong support for the Web of Life course with the teacher sample expressing strong satisfaction with 24 items and moderate satisfaction with 7 items related to aspects of the Web of Life course. Teachers were undecided with 10 items and showed strong or moderate dissatisfaction with 8 items. Those categories which created most dissatisfaction were related to the final externally set examination at the end of grade 12, the current population of students taking the biology course, and the knowledge and skills of biology teachers. The paper concludes by making recommendations for improving inquiry teaching in the Web of Life biology course and for developing an alternative course to cater for the diverse range of students currently studying biology in grades 11 and 12.

SCIENCE TEACHERS' ATTITUDES AND BELIEFS ABOUT THE EFFECTIVENESS OF WRITING FOR LEARNING AND TEACHING SCIENCE

Karen Sullenger
University of Georgia
Athens, GA 30605

Writing across the curriculum (WAC) is a movement, an effort to encourage teachers of all subjects to become "teachers of writing." In the United States the movement is taking the form of writing projects and programs which seek to increase the content teacher's awareness of writing and cooperation in improving student's writing skills. Unfortunately, many content-area teachers perceive this emphasis on writing as shouldering a burden that rightfully belongs to English teachers, not as a means of improving students' learning.

The exact relationship between writing and learning science has not been completely established. Although composition and linguistic researchers have begun to construct the theoretical framework, they may be limited by their lack of understanding of science as a discipline. If writing as a way of making meaning in science is to be fully explored and validated, researchers within the science and science education community must become involved. Those familiar with the conventions and constructs of a discipline, as well as the discipline's reasoning processes, are in the best position to identify changes in learning promoted by writing.

The purposes of this study are to: (1) identify and describe science teachers' attitudes and beliefs about their own writing; (2) identify and describe their attitudes and beliefs about teaching and evaluating writing in science; and (3) determine how these attitudes and beliefs are reflected in their classrooms. One significance of this study is that it represents a first step in addressing questions from within the science education community.

The year-long study involved a two-phase, pyramid research design consisting of a questionnaire followed by interviews. This type of qualitative design was selected because it offered the breadth of a survey with the depth of individual interviews and classroom observation. This report considers the findings from the questionnaire phase.

The findings seem to suggest that science teachers' attitudes and beliefs concerning their own writing and writing to learn in science are stronger and more positive than their attitudes and beliefs concerning teaching and evaluating writing. Responding science teachers appear to have ambivalent feelings toward their students' writing, teaching writing, and evaluating writing. The responding science teachers appear to view themselves more as users of writing than teachers or evaluators of writing. These science teachers see success in science as positively related to a student's writing ability and vocabulary. Further, they think that essay questions are necessary if one is to find out what students understand about the science concepts and principles taught. However, these science teachers do not support teaching writing in science. There is also evidence to suggest that the concepts, "teaching and evaluating writing," are not clearly defined in the minds of the responding science teachers.

This could indicate that, while science teachers have definite ideas about their own writing, they do not have a well developed understanding or beliefs about the use of writing the classroom. These science teachers may not know how to develop or address the importance of writing in their classes. What could be perceived as science teachers only wanting to use writing in science may be a need to understand the role writing could play in directing and assessing learning.

A CURRICULUM STRATEGY THAT EXPANDS TIME FOR IN-DEPTH ELEMENTARY SCIENCE INSTRUCTION BY USING SCIENCE-BASED READING STRATEGIES: EFFECTS OF A YEAR-LONG STUDY IN GRADE FOUR

Nancy R. Romance
Florida Atlantic University
Boca Raton, FL 33431

Michael R. Vitale
East Carolina University
Greenville, NC 27858

This year-long study increased the instructional time allocated for in-depth science teaching by replacing the district's basal reading program (i.e., series instructional activities and reading/workbook materials) with science-content based strategies to facilitate reading comprehension skills. In doing so, the study investigated the combined effect of these curricular components upon student achievement, attitudes, and self-confidence in both science and reading over the school year. In the study, teachers in three fourth-grade classrooms each incorporated applied reading (and language arts) objectives into science reading activities as part of a daily expanded in-depth science teaching block that emphasized hands-on activities and science process skills and that encompassed the total instructional time originally allocated to reading and science. Results showed that experimental students, compared to demographically similar controls, not only displayed greater standardized test achievement on the Iowa Test of Basic Skills (ITBS) reading and the Metropolitan Achievement Test (MAT) science, but also more positive attitudes and self-confidence toward science activities and more positive attitudes toward reading. Discussed are implications for curriculum reform and future research.

HOW THE DESIGN OF INSTRUCTIONAL MATERIALS CAN FURTHER THE IMPLEMENTATION OF AN ELEMENTARY SCIENCE CURRICULUM

Jan J.H. Van Den Akker
University of Twente
Enschede, The Netherlands

This paper will present an overview of a lengthy research project (1982-1990) concerning problems in the implementation of a Dutch curriculum for elementary science. The focus of the research is on the potential influence of the design and codification of instructional materials on the planning and execution of science lessons by teachers in their initial implementation efforts.

The context for our research activities is a national curriculum development project for elementary science (acronym: NOB) initiated in 1978. The main NOB characteristics are comparable with those of earlier British and American science projects: (a) integration of elements from various disciplines such as biology, and chemistry; and (b) an emphasis on inquiry learning.

Although the NOB project made extensive efforts to embed the development work in diffusion-oriented activities (in-service training, conferences, local guidance, and the like), the curriculum materials themselves remain the primary vehicle for the dissemination and implementation of the development ideas and proposals.

For that reason we were very interested in the (difficult) problems facing designers of curriculum documents:

* How to attain sufficient clarity and specificity so that those who are supposed to be instructed by a curriculum document know exactly what they are being advised to do?
* How to make a document easy to consult, attractive, helpful and acceptable so that it will be used in a variety of settings?

Our initial problem analysis revealed the following central implementation problems of teachers:

* great difficulty in changing the teaching role, especially in regard to the forms of inquiry learning;
* a lack of background knowledge and confidence in subject matter and skills;
* lesson preparation as a complex and time-consuming chore;
* an unclear view of, and little realization of, learning effects with the pupils.

Our problem analysis led us to a set of hypotheses about potentially fruitful characteristics of science curriculum materials. For each of the earlier mentioned, central implementation problems (lesson preparation, subject matter, teaching role, learner effects) we identified which functions the materials can fulfill for the teacher and which characteristics of the materials are necessary for those functions.

These characteristics were applied in the reconstruction of already available lesson material. A field experiment with 40 teachers was carried out to compare the effects of the transformed and original materials. The results were strongly in favor of the transformed materials. The lessons that were taught using the experimental materials were much more in accord with the intentions of the developers than the lessons based on the original materials. It was especially striking that the teachers of the experimental group were more successful in creating and maintaining the intended inquiry approach throughout the lesson.

This research suggests a high degree of effectiveness in starting up the learning process that is associated with curriculum change when the curricular materials stimulate the teachers to a more elaborate and accurate 'internal dialogue' about the what, when, how, and why of their teaching role, and provide them with clear advice about the implications of these matters for classroom practice.

Inspired by the encouraging results of this experiment, we started in 1986 a follow-up study to test the generalizibility of the findings. In this R&D project an effort is made to apply the same design approach on 30 other short lesson series, spread over different science topics and different age groups. The first half of this project (1986-1988) has been largely spent on development activities, while the second half (1988-1990) is especially focused on evaluation of the materials with a new, large group of teachers. This paper will also contain a description of the procedures and results of the second study.

EITHER/OR = NEITHER/NOR: CASE STUDY ON THE IMPLEMENTATION OF A PROBLEM SOLVING CURRICULUM IN ELEMENTARY SCIENCE

Mary Lee Martens
East Williston Schools
East Williston, NY 11596

The change from a content-oriented, textbook dependent way of teaching science to a hands-on problem solving approach is particularly difficult because it involves the possible use of new or revised materials and teaching approaches and the possible alteration of beliefs. Additionally, there is a lack of agreement about what is meant by problem solving among those responsible for its implementation. This interpretive study focuses on a veteran elementary teacher with teaching abilities and personal qualities that suggested that hers would be a relatively easy and certainly possible change. Data collection spanned a period of one year and included classroom observations, interviews, and document analysis.

Findings included the following: 1) Ample materials were available but the teacher often used more of them than students could handle in one lesson. 2) While endeavoring to integrate materials from as many disciplines as possible, the teacher missed opportunities to develop in-depth comprehension of important science concepts. 3) An unintended consequence of the teacher giving students too many materials and not enough direction was that the students felt free to investigate their own problems. 4) The teacher was willing to use spontaneously occurring discrepancies as a starting point for problem solving when she perceived herself as knowledgeable about the cause.

Environmental and personal factors alone are insufficient to explain how this teacher is attempting to change the way she teaches science. She is caught in a discrepancy between wanting her students to learn the right information and simultaneously wanting them to ask their own questions ar discover for themselves. She clearly views teaching as either impartir

previously mastered correct content or allowing students to generate their own questions. Unable to resolve this discrepancy, she tries to do both. The result is often a great deal of confusion and wasted time as she flounders and allows lessons to proceed without direction.

A serious risk underlies the discrepancy which persists in this teacher's thinking. As long as she remains locked in an either/or perspective, she is likely to do neither the imparting of content nor the facilitating of student-made connections very effectively. One way in which this discrepancy might be resolved is through the practice of reflection-in-action. There are indeed basic concepts and scientific principles which are the "right" information and it is highly appropriate for teachers to structure activities which will engage elementary students and enable them to understand these concepts. Within such structure, however, students create their own understandings whether teachers acknowledge it or not. Reflection-in-action holds potential for resolving the dilemma in which this teacher is trapped.

LEARNING BIOLOGY IN A COOPERATIVE MODE IN NINTH GRADE HETEROGENEOUS CLASSROOMS: STUDENTS' ACHIEVEMENTS BY METHOD AND GENDER

Reuven Lazarowitz
Miri Galon
Israeli Institute of Technology
Haifa, Israel 32000

Cooperative instruction and learning in small heterogeneous groups was found to enhance students' achievement, process skills, self esteem, and classroom learning environment in junior and senior high school science.

In this study, the subject of "Cell Division" (Mitosis and Meiosis) was taught to ninth grade students by using peer tutoring in small investigative group approach. This cooperative mode of learning is a combination of the jigsaw method developed by Aronson and group investigation method by Sharan and Hertz-Lazarowitz. The cooperative method of instruction is an instructional attempt to meet students' different abilities and needs in a heterogeneous classroom.

The study included 201 students from 6 classrooms; 95 students were instructed in the cooperative method, and formed the experimental group, and 106 students were instructed in a frontal classroom - laboratory approach and represented the control group. The study lasted five weeks, three hours per week in two junior high schools.

The entry behavior of the students in both groups was tested for general knowledge in biology, pre-requisites needed for the subject to be learned, and prior knowledge on the cell division.

The post-test checked students' knowledge gained during the study on the cell division subject. Both tests used multiple choice questions. The mean scores of the students in both tests were treated by an analysis of covariance by method and gender.

The results indicated that, while the entry behavior of both groups was equal, the experimental group achieved significantly higher mean scores on the posttest than the control group. Within the experimental group, no significant differences were found between the mean scores of the boys and of the girls. The results show that students characterized as low achievers profited and gained more in the experimental group than their counterparts in the control group.

The appropriateness of the cooperative method of instruction as a mode of learning science in heterogeneous classrooms in junior high school is discussed in the light of the problem posed by this method.

COGNITIVE CONFLICT AND COOPERATIVE LEARNING

Gail Jones
University of North Carolina at Chapel Hill
Chapel Hill, NC 27599-3500

This study compared the effects of cooperative learning groups and traditional dyads in moving students through misconceptions about temperature to a more acceptable cognitive framework. Students from grades 3, 4 and 5 in two rural elementary schools participated in the study. Students completed a pretest, a cognitive conflict laboratory activity and a posttest that measured qualitative and quantitative aspects of their understanding of temperature. The control group completed the activity in traditional dyads and the experimental group completed the activity in cooperative learning groups composed of four students. The results indicated that the conflict training was effective in changing students' concepts of temperature, but the cooperative learning groups were no more effective than the traditional dyads.

COOPERATIVE LEARNING AND GROUP EDUCATIONAL MODULES: EFFECTS ON COGNITIVE ACHIEVEMENT OF HIGH SCHOOL BIOLOGY STUDENTS

Scott B. Watson
East Carolina University
Greenville, NC 27858-4353

The purpose of this study was to examine the effects of the Group Educational Modules (GEM) materials and cooperative learning techniques on the achievement of high school biology students. GEM materials are self-instructional packets designed for use with groups of high school biology students. Cooperative learning is a classroom learning environment in which students work in small, mixed ability groups toward a common goal and are rewarded for doing well as a group.

A 2 x 2 factorial design was used in this study. The independent variables considered included: (1) participation of students in the GEM project, and (2) use of cooperative learning techniques including heterogeneous grouping and group incentives. The dependent variables for all treatment groups were scores on the instrument developed for this study.

A total of 11 teachers with 36 classes and 715 students was included in this study. All teachers involved covered the same general subject matter during the study period. An analysis of co-variance (ANCOVA) was used as the data analysis procedure. Significant differences were found in the achievement of students using GEM materials and those using traditional instructional approaches. The use of cooperative learning produced significant differences when compared to traditional classroom structures.

The results of this study indicate that allowing students to work together in groups, whether heteroyeneous or not, may be one of the reasons for t e success of both the GEM materials and cooperative learning. The implication is that there is an additive effect in using the components of cooperative learning, and that heterogeneous grouping and group incentives appear necessary to maximize achievement.

A DESCRIPTIVE STUDY OF LIFE AND PHYSICAL SCIENCE ALTERNATIVE CONCEPTS OF PRESERVICE ELEMENTARY TEACHERS

Sophia Yani Arditzoglou
Frank E. Crawley
University of Texas at Austin
Austin, TX 78712

The purpose of this study was to identify the alternative life and physical science concepts possessed by preservice elementary science teachers (n=49). Science textbooks appropriate for grades 5 and 6 were surveyed, and the literature on alternative science concepts was reviewed. These processes produced a pool of 16 life and physical science concepts found both in the textbooks and the literature on alternative concepts. From this pool, items were constructed to identify preservice elementary teachers' understanding of the life and physical science topics. Results revealed teachers possessed a total of 36 alternative concepts in the life sciences and 49 in the physical sciences.

THE EFFECT OF CONFIDENCE AND EFFECTIVENESS ON THE BIOLOGY CONTENT COGNITIVE STRUCTURE OF TEACHERS

Patricia L. Hauslein
Southeastern Louisiana University
Hammond, LA 70402

Ronald Good
Louisiana State University
Baton Rouge, LA 70803

The purpose of this study was to elucidate the substantive structure of specific content knowledge in the discipline of biology by comparing the cognitive structure of the science practitioner, both student and expert, with the cognitive structure of the science teacher, again both student and expert. The particular aspect of this study focused on the relationship between teaching effectiveness and teaching confidence and cognitive structure. It was the aim of this study to determine what role these characteristics might have on the cognitive structure of teachers during the transition from novice to expert.

The F-Sort of Biology Concepts was used to assess understanding of the relationships among 37 biology concepts by five groups:

1. Preservice secondary science teachers (PSR)
2. Inservice biology teachers with 1-3 years of teaching experience (NOV).
3. Inservice biology teachers with 5 or more years of experience (EXP).
4. Scientists in any biological science field (e.g., microbiology, botany) (SCI).
5. College seniors majoring in biology (MAJ).

Two subgroups (confident/less confident and effective/less effective) were generated from the inservice teachers.

Data collected from the F-Sort of Biology Concepts were analyzed using Latent Partition Analysis and Alpha Factor Analysis with additional interpretation from multidimensional scaling. The subjects were asked to think aloud as they performed the F-Sort and each session was audio-taped for later analysis.

The results of a previous study indicated that the biology majors, novice teachers and preservice teachers were distinguishable from the experienced teachers and scientists by a dimension based on a deep versus surface structure understanding of the concepts. This dimension reflects the extent of order and hierarchical nature of the cognitive structure. The second dimension of the cognitive distance MDS reflected the degree of cross-linking of the cognitive structure. The manifestation of this is the scientists' and novices' ability and nature of fluid thought about these

concepts. That is, they were not fixed on only one classification but were able to see the inter-relationships of the concepts. The preservice teachers also fell toward the fluid end of this dimension. Because they are also at the surface structure end of the first dimension, this suggests a cognitive structure which has nearly everything linked to everything else, fluidity of thought perhaps, but highly unstructured with questionable usefulness.

An additional description of the horizontal dimension is one of procedural versus conceptual, much like that of the genetic counselors and faculty members described in Smith's study. The experienced teachers and majors have a more procedural knowledge of the concepts. For the teachers that means content knowledge which is intimately tied to the procedures for teaching it.

Not surprisingly, the subgroups established in this study from the teacher groups fall toward the fixed/procedural end of the horizontal dimension. Both subgroups, however, were separated on the deep vs. surface dimension; the confident and effective teachers falling more toward the deep end of the dimension. The apparent transition from poorly organized to highly organized cognitive structures when comparing the PSR, NOV and EXP respectively, also seems to be indicated in the teachers' level of confidence and effectiveness as well. The confident and effective teachers have a more organized and deeper cognitive structure although still somewhat rigidly determined by the curriculum.

A COMPARATIVE STUDY OF THE PEDAGOGICAL CONTENT KNOWLEDGE OF EXPERIENCED AND NOVICE CHEMICAL DEMONSTRATORS

Christian P. Clermont
Hilda Borko
University of Maryland
College Park, MD 20742

Joseph S. Krajcik
University of Michigan
Ann Arbor, MI 48109

This study examined the pedagogical content knowledge (PCK) of experienced and novice chemical demonstrators. Teachers use their PCK to make decisions on how to teach very specific subject matter topics to students of various ages and abilities. Shulman's model, which describes the major characteristics of this knowledge base, provided a theoretical base for this study.

A clinical interview served as a probe of the pedagogical content knowledge held by a group of experienced and novice chemical demonstrators. Eight science teachers with experience in conducting chemical demonstration workshops served as experienced chemical demonstrators.

The clinical interview consisted of a critical-stop task and a semi-structured interview which probed teachers' knowledge of demonstrating two basic chemical concepts, density and air pressure. The critical-stop task required subjects to view two videotaped chemical demonstrations and on the second viewing stop the tape at critical segments to think aloud about what they pereived contributed to effective and ineffective chemical demonstrating. The semi-structured interview consisted of several questions concerning the videotaped presentation and several questions on alternative chemical demonstrations on the targeted concepts. Both the critical-stop task and the semi-structured interview were audiotaped and transcribed.

A quantitative and qualitative domain, taxonomic, and theme analysis was conducted on the verbal data. The data showed that the experienced chemical demonstrators were able to discuss numerous chemical demonstrations and demonstration variations on the targeted concepts, density and air pressure. Their responses were considerably more extensive and detailed than the demonstrations and variations discussed by novices. The experienced demonstrators were also more cognizant of the complexity of several chemical demonstrations, how these complexities could interfere with learning, and how simplified variations of these chemical demonstrations could promote concept learning. Their verbalizations also contained fewer references to pedagogically unsound chemical demonstrations on the targeted concepts than those of novices. Each of these differences reflect characteristics of experienced and novice chemical demonstrators' PCK. A frequency analysis of the interview protocols further revealed that novices tended to focus more on generic teaching issues while the experienced demonstrators discussed more issues pertaining to pedagogical content knowledge.

This research provides empirical evidence that pedagogical content knowledge of science teachers differs substantially between experienced and novice chemical demonstrators. Understanding the differences in PCK of experienced and novice science teachers can be helpful in planning teacher preparation programs as well as inservice programs that promote the professional development of science teachers.

THE NATURE OF VERBAL EXPLANATIONS GIVEN BY SCIENCE TEACHERS

Zoubeida Dagher
University of Delaware
Newark, DE 19716

George W. Cossman
The University of Iowa
Iowa City, IA 52242

The purpose of this study was to explore and describe some of the types of explanations used by junior high science teachers in a natural classroom setting. Theoretical and philosophical frameworks related to the nature of scientific explanations (as perceived by philosophers of science), the nature of teacher explanations (as perceived by philosophers of education),

and everyday explanations, served a referential rather than a guiding role for the work. Twenty teachers belonging to 13 school districts were observed intermittently over a period of two months. During those observations, technological records in the form of audiotapes were obtained and supplemented with field notes. The audiotapes were later transcribed for analysis. Using "explanation" as the thematic unit of analysis, a qualitative method of analysis advocated by Glaser and Strauss was used to generate explanatory types. This method involved constant comparison of explanations assigned to the same category. Inductive and deductive procedures were used side by side to create, or merge, types as the analysis proceeded. A system of ten types resulted: practical, metaphysical, purposive/intentional, anthropomorphic, functional, genetic, mechanical, analogical, rational, tautological. These types were organized into a framework or model by adding a network of subsuming categories. The resulting scheme provides a tool for the analysis of teacher explanations that promises to be useful in research, teacher education and other settings.

Symposium

A CROSS-NATIONAL STUDY OF SCIENCE LABORATORY CLASSROOM ENVIRONMENTS

Barry J. Fraser
Geoff J. Giddings
Curtin University of Technology
Perth, Western Australia 6001

Avi Hofstein
Weizmann Institute of Science
Rehovot, Israel

Alan K. Griffiths
Memorial University of Newfoundland
St. John's, Newfoundland, Canada, A1B 3X8

Dale G. Merkle
Shippensburg University of Pennsylvania
Shippensburg, PA 17257

A strong tradition in science education research in elementary and high schools has involved several widely-used instruments assessing student or teacher perceptions of characteristics of actual or preferred classroom psychosocial environment. Existing instruments, however, are unsuitable for one of the most important settings in science teaching, namely, the science laboratory class. Consequently, the present research had as its purpose the development and validation of a new instrument, the Science Laboratory Environment Inventory (SLEI), specifically suited to science laboratory environments at either the senior high school or higher education level. The SLEI assesses students' or teachers' perceptions of the following eight dimensions of actual or preferred classroom environment: Teacher Supportiveness, Involvement, Student Cohesiveness, Open-Endedness, Integration, Organization, Rule Clarity and Material Environment. A distinctive feature of the design of the study was that the new instrument was field-tested simultaneously in five different countries, namely, the USA, Canada, England, Australia, and Israel. The total sample consisted of over 3,000 students in over 100 individual laboratory classes, together with the teachers of these classes. Various item and factor analyses attested to each SLEI scale's internal consistency reliability, discriminant validity, ability to differentiate between the perceptions of students in different classes, and predictive validity (in terms of predicting student attitudes toward laboratory classes). Validity data are reported separately for teacher and student forms, for actual and preferred forms, for different countries, and using the individual student and the class mean as the unit of analysis. Within-country and between-country analyses were used to shed light on various important research questions including the differences between actual and preferred environments, gender differences in perceptions of actual and preferred environment, the relationship between the science laboratory environment and attitude toward science, differences between school and college laboratory classes,

differences between teachers' and students' perceptions of the same laboratory classes, and differences between laboratory classes in different science subjects (physics, chemistry, biology). Overall, the data generated from each of the countries provided considerable evidence supporting the cross-national validity and applicability of the SLEI.

AN INVESTIGATION OF THE RELATIONSHIP BETWEEN LOGICAL THINKING STRUCTURES AND THE ABILITY TO CONSTRUCT AND INTERPRET LINE GRAPHS

Craig A. Berg
University of Wisconsin-Milwaukee
Milwaukee, WI 53211

Research was done to investigate the relationship between logical thinking structures and the ability to construct and interpret graphs. In addition, the possible hierarchical relationship between elements of graphing was examined.

Seventy-two subjects in 7th, 9th, and 11th grades were administered individual Piagetian tasks to assess six specific mental structures. Clinical interviews were also used to assess graphing abilities. Some of the graphing questions were modified from multiple choice questions utilized in prior graphing research. In addition to the clinical graphing interview, all subjects were administered a modified version of a multiple-choice graphing instrument (TOGS).

The results indicate significant relationships of logical thinking to graphing. Subjects who showed evidence of proportional reasoning did significantly better on many graphing situations. Student difficulties with "slope versus height" were the result of incorrect interpretation of the question, lack of proportional reasoning, and additional problems of choosing the beginning or endpoint of the line. Difficulties in choosing the part of the graph with the greatest "rate of change" were significantly related to proportional reasoning (.01). The other mental structures assessed, including Multiplicative Seriation, Euclidean and Multiplicative Measurement structures positively influenced graphing abilities. Students who did not have the logical thinking structures were more likely to be dependent upon perceptual cues and less able to interpret or construct graphs correctly. Locating points on a graph without a grid was significantly related to horizontal-vertical frames of reference (.02).

A definite hierarchy of the elements of graphing was not found. The multiple-choice question which supposedly assessed specific aspects of graphing produced widely varying results. Elements such as "determining the greatest rate of change" and many other aspects of graphing dependent upon proportional reasoning were substantially more difficult than elements which subjects could successfully answer by memorized responses or answer in accordance with perceptual cues.

In addition, the results obtained through the clinical graphing interviews were very different from similar questions assessed through multiple-choice formats in other research studies, indicating that multiple-choice questions may not be a valid measure of graphing abilities.

THE EFFECT OF SIMULTANEOUS MOTION PRESENTATION AND GRAPH GENERATION IN A KINEMATICS LAB

Robert J. Beichner
SUNY at Buffalo
Buffalo, NY 14260

Real-time Microcomputer-based Lab (MBL) experiments allow students to "see" and, at least in kinematics exercises, "feel" the connection between a physical event and its graphical representation. In Brasell's examination of the sonic ranging MBL, a delay of graphing by only 20 seconds diminished the impact of the MBL exercises. This article describes a study where kinesthetic feedback was completely removed by giving students only visual replications of a motion situation. Graph production was synchronized with motion re-animation so that students still saw a moving object and its kinematics graph simultaneously. Results indicate that this technique did not have a substantial educational advantage over traditional instruction. Since Brasell and others have demonstrated the superiority of microcomputer-based labs, this may indicate that visual juxtaposition is not the relevant variable producing the educational impact of real-time MBL. Immediate student control of the physical event and its graphical representation might be what makes MBL effective and, in the case of kinematics laboratories, kinesthetic feedback could be the most important component of the MBL learning experience. Further studies are needed in order to clarify this point.

THE EXHIBIT INTERPRETER: AN ATTENTION-FOCUSER IN SCIENCE MUSEUMS

Elizabeth M. Bennett
North Carolina Museum of Life and Science
Durham, NC 27704

Ertle Thompson
University of Virginia
Charlottesville, VA 22903

Educators and museum evaluators are attempting to understand the influence science museums have upon science education and the kinds of learning experiences visitors have in the multisensory, informal learning environments of science museums. Some research has centered around the amount of visitor attention which is focused upon museum exhibits and hands-on experiences available. However, very little study has been given to the exhibit interpreter as an attention-focuser in the complementary role of interfacing between the exhibit and the visitors. In this role the interpreter assists visitors in attending to the exhibits by explaining or showing how the exhibit operates, by pointing out scientific principles illustrated by the exhibit, or by complementing the exhibit information in other ways. The purpose of this study was to determine whether the exhibit interpreter, in the complementary role of interfacing between the exhibits and visitors, was effective in attracting and focusing the attention of the casual visitor in a science museum.

The study was conducted in the spring of 1988 in two science museums: the Science Museum of Virginia in Richmond, Virginia, and Discovery Place in Charlotte, North Carolina. Two data gathering observations were made at each museum, one on a weekday and one on a weekend day. The exhibit areas in each museum received both destination and flow-through traffic and could be filmed unobtrusively by a stationary camera. The data necessary for assessing the interpreter's effectiveness as an attention-focuser were gathered during review of the tapes of these observations. Statistics used to analyze the data included a z-test for proportionality, a chi-square, and analysis of variance.

The findings and conclusions of this study were: 1) The presence of the exhibit interpreter significantly influenced the increase in time spent and in the number of attending behaviors demonstrated in the exhibit area on weekdays at each museum. 2) At both museums on weekend days there was a trend toward increased time spent and the number of attending behaviors demonstrated in the exhibit area while the interpreter was present. 3) Age and the interaction of age and the interpreter presence were not consistent influences on time spent or number of attending behaviors demonstrated in either museum. However, it was observed that adults spent a longer time in the exhibit area in the Science Museum of Virginia and teens and children spent more time in the exhibit area at Discovery Place.

The exhibit interpreter possesses many of the attributes researchers have identified as successful attention-focusing devices: positive feedback, movement, potential for interaction, sound, guidance, complexity and familiarity. The findings of this study will assist science museum educators in making decisions about the effective use of exhibit interpreters. Recommendations for a large-scale study of the effectiveness of exhibit interpreters on learning in a science museum and for assessing particular interpreter techniques were made.

HIERARCHICAL LEVELS OF DIFFICULTY FOR TEST ITEMS WITH VISUAL ILLUSTRATIONS

Edith Yi-Tan Chang
Teachers College Columbia University
New York, NY 10027

Bloom as well as others have classified the level of difficulty for written test items. But, the literature is not clear as to whether visual illustrations play a "clarifying" role or add little to the understanding of the written material.

Our study is based on the U.S. data from the International Association for the Evaluation of Educational Achievement for 1970, 1983 and 1986. The total sample is 26,744 students from the 5th, 9th and 12th grades. There are a total of 90 test items with visual illustrations, 30 of which were repeated in 1970, 1983 and 1986. Visual illustration is defined as "any item with illustrations or tables which required the students to read on the x and y axes."

The items were grouped in the following categories:

1. Items on which the illustration serves no role of clarification whatsoever or visually-irrelevant.
2. Items on which the illustration clarified the question. In other words, they were visually-illustrative.
3. Illustrations which contain the information for the questions or answers. There were two levels of difficulty on this type of items:
   a. Visual-application which required the student to read the information and apply the correct answer.
   b. Visual-inference which required the student to deduce or infer the information from the illustration.

The items in the last category all required process skills. Among the test items there was one item whose illustration did not serve any purpose. On this item the U.S. students as well as others, e.g., England, scored very poorly.

In the other categories our study found that visual illustrations which illustrated the question were not necessarily easier for the students because they were dependent on the subject matter of the test item and, therefore, subject to the students' cognitive exposure to the topic. The 5th graders scored well on visual-application type of items. But they did have difficulty on the visual-inference type of items which required the students to deduce or infer the information from the illustration. This was also true for the 9th graders. The 12th graders scored substantially higher on these items, thus suggesting the effect of maturation and the existence of a hierarchical level of difficulties.

CHANGING THE CONVERSATION: WHEN SCIENCE TEACHERS START TALKING ABOUT INSTRUCTION...

Antonio Bettencourt
James J. Gallagher
Michigan State University
East Lansing, MI 48824

The purpose of the study reported here is to investigate: 1) What happens when science teachers interact with each other about instructional matters on a frequent basis, and 2) What are some of the aspects of the school environment that make such conversation possible and fruitful?

The problem of teacher isolation and lack of collegial relationships has been extensively documented and considered one of the obstacles to improvement of instruction. The study reported here analyzes some empirical evidence about how that situation can change in junior high science.

The study is part of a larger collaborative research and intervention project in junior high school science and mathematics. The collaboration was between a research institute, a school district, and a teachers' union. Four junior high schools in an urban midwestern school district agreed to participate in the project. In each of them the science and mathematics faculty chose one of them to be, respectively, the Science and the Mathematics Support Teacher. The study only deals with data pertaining to the four science support teachers.

The data from the study come in various forms and from various sources: inventories, structured interviews, fieldnotes, transcripts of audiotapes, support teacher logs, meeting agendas and notes, exemplars of student work like worksheets, tests, write-ups, etc..

The findings are that extended interaction of science teachers about instructional matters feeds into the improvement of their practice, motivates experimentation, and that the transformations feedback into the conversation.

The study findings indicate that teachers' isolation is not impossible to break. There needs to be at least a departmental effort that is based on the teachers and that has administrative support.

EXPANDING MIDDLE SCHOOL SCIENCE TEACHERS' ROLE CONCEPTUALIZATIONS THROUGH COLLABORATION AND REFLECTION

Sarah L. Ulerick
Anthony W. Lorsbach
Florida State University
Tallahassee, FL 32306-3032

This study examined the processes of collaboration and reflection involved in team teaching and planning in a middle school science program. Two broad questions were addressed: how do teachers with differing views negotiate plans for teaching and assessing learning; and how does reflection on practice and in practice facilitate changes in teachers' conceptualizations of their roles? Using an interpretive methodology, we develop assertions pertaining to the processes of team teaching and planning. We found that a high degree of trust was essential to negotiating plans; that the value placed by teachers on philosophical reflections was context dependent; that the nature of the teaching "infrastructure" influenced teaching practices and reflections on practices; and that team teaching allowed teachers to experience new role conceptualizations. As a result of collaborating about plans and reflecting about teaching and learning, teachers' metaphors for describing their role conceptualizations changed over time. New metaphors emerged, revealing an expended view of professional teaching roles and revisions in beliefs about the nature of science and learning. The findings of the study reconfirm the importance of reflective practice and suggest that team teaching provides a structural context for collaboration and reflection by removing the walls of isolation between teachers.

CONSTRUCTIVIST IDEAS AS A BASIS FOR INSERVICE TEACHER EDUCATION: FIRST YEAR RESULTS OF A PROGRAM TO ENHANCE MIDDLE SCHOOL UNDERSTANDING OF TARGET CONCEPTS IN THE AREA OF ELECTRICITY AND SIMPLE CIRCUITRY

James A. Shymansky
John Dunkhase
Obed Norman
Hui Ju Huang
Chin Tang Liu
University of Iowa
Iowa City, IA 52242

Charles Matthews
Maharishi International University
Fairfield, IA 52556

Zoubeida Dagher
University of Delaware
Newark, DE 19716

Translating theory into practice is what this paper is about: it is a report on the effects of an inservice program of teacher education which attempts to apply constructivist learning ideas in the context of classroom instruction, i.e., the effectiveness of such an approach in enhancing middle school teachers' content background and broad teaching skills. Concepts in the area of electricity and simple circuitry served as the content focus and the middle school level (grades 4-8) as the context for the study.

This study was conducted as part of the "Science Teacher As Action Researcher" (STAAR) project -- a funded project designed to develop a middle school science teacher enhancement model. The idea of STAAR is to engage science teachers in studies of their students' understanding and thinking about a particular science topic (action research) in order to get the teachers to focus on substantive science content and teaching strategies.

Data collected from two middle school teacher groups in two successive years of the project are analyzed and discussed. Specific workshop activities included: analyzing student explanations from videotaped vignettes filmed in a 5/6th grade science class; learning how to use concept maps and classroom interactive strategies to ascertain student ideas about target concepts; replicating student-built circuits and interacting with content experts about the circuits and how to challenge students' ideas; and working with small groups of middle school students to refine interactive skills and strategies for using concept mapping. During the summer workshops, teachers prepared to implement the action research strategy in their own classroom.

Teacher understanding of target concepts was determined indirectly from teacher documents generated during the workshop: responses to prediction sheets and analysis of clinical interview data collected on their own students and personal concept maps, responses to prediction sheets and analyses of student concept maps and explanations.

Analyses of transcripts of teachers interviewing their own students (Year 1), teacher-made concept maps (Years 1 & 2), and prediction activity responses from teachers (Years 1 & 2) reveal that teachers improved in their understanding of concepts in electricity and simple circuitry. Anecdotal and teacher journal data suggest that the action research focus did reduce the embarrassment and anxiety of "not knowing" and made it easier for the teachers to examine and contrast their own ideas with the scientific ones. The transcripts also showed that teachers had great difficulty probing beyond the factual level. But the teachers were able to recognize that effective strategies are a function of form and substance.

These early data suggest that an action research approach focusing on analyses of student ideas related to a target topic is effective in enhancing teacher understanding of the target concepts and broadening teacher skills for assessing student understanding and facilitating conceptual change.

AN EXPLORATORY STUDY OF A PLAY-BASED CENTER APPROACH TO LEARNING CHEMISTRY IN AN EARLY CHILDHOOD PROGRAM

John T. Norman
Thomas E. Taddonio
Wayne State University
Detroit, MI 48202

The purpose of this exploratory study was to evaluate the effectiveness of seven chemistry learning centers for use in a play-based preschool education program. The seven different centers were evaluated for their ability to meet certain cognitive, socioemotional, and language goals. Also, the centers were evaluated with regard to ten developmental appropriateness criteria defined by Smith.

The chemistry centers evaluated were: Observing Color Changes, Making Bubbles, Classifying Odors, Sink or Float, Using a Thermometer, Cooking, and Balancing.

Videotapes were taken of each center and anecdotal records were made by the teacher. Both qualitative and quantitative data were recorded and analyzed.

All seven of the chemistry centers were successful and appropriate for preschool students and seemed to promote cognitive, socioemotional, and language goals. Overall, the centers that were the most developmentally appropriate and also were successful in developing the aforementioned goals were: Observing Color Changes, Bubbles, and Balancing. The Cooking center, while promoting language goals effectively, was not as strong in promoting socioemotional goals, particularly autonomy. The two centers that ranked lowest overall for appropriateness and for meeting the goals were the Thermometer and Classifying Odors centers. Perhaps these centers depended too strongly on the teacher for them to be successful as play-based centers.

APPLIED AND THEORETICAL KNOWLEDGE OF CHEMISTRY CONCEPTS

Michael R. Abraham
University of Oklahoma
Norman, OK 73019-0370

Abdullateef H. Haidar
Sana'a University
Yemen Arab Republic

This study compares 183 high school chemistry students' applied and theoretical knowledge of concepts based on the particulate theory. The concepts are dissolution, diffusion, effusion, and states of matter. A two-form instrument, called the Physical Changes Concepts Test (PCCT), was developed for this study. The Application Form measures students' knowledge using everyday language. The Theoretical Form measures students' knowledge using scientific language. Students' formal reasoning ability was measured using the Test of Logical Thinking (TOLT). The overall results of the two forms of the PCCT indicate that more than 40% of the students displayed alternative conceptions (ACs) of the concepts covered in the PCCT. The study found that students' formal reasoning ability and their pre-existing knowledge have a significant effect on their conceptions and use of the particulate theory. The analysis of the nature of students' ACs and their use of the particulate theory revealed a significant difference between students' applied and theoretical knowledge.

SCIENCE ACTIVITIES CHILDREN CHOOSE OUTSIDE THE SCHOOL: A DESCRIPTIVE STUDY WITH IMPLICATIONS FOR CLASSROOM INSTRUCTION

Elisabeth Charron
Montana State University
Bozeman, MT 59717

The purpose of this study was to investigate the nature and scope of the science activities which third and fourth grade children engaged in outside of school in one community, a small college town in the Northwest. In this qualitative study, which is based primarily upon interview and observational data, patterns in the children's extracurricular science activities are described, and classroom applications of the findings are proposed. The study involved eleven third graders and twelve fourth graders attending the same school in a professional to working class neighborhood which was representative of the community as a whole. The researcher's contact with the pupils, their teachers, and parents occurred during a nine month period. Data gathering techniques included formal interviews of the pupils, their teachers, and selected parents; informal interviews; and participant observation in classrooms and homes. Patterns in the data were identified using the constant comparative method of data analysis. Selected findings include the following: (1) the majority of the students reported regularly participating in a range of science activities after school and on weekends; (2) the categories of science activities preferred by the students included experimenting, observing, collecting and thinking; (3) the students' science activities often involved natural history topics, but interest in other science topics was sometimes reported; (4) the science activities described by the students usually took place in, or near, their homes and did not involve formal youth programs or organizations; (5) the pupils typically conducted science activities alone, or with close relatives or friends; (6) the pupils' nonschool science activities often were not generated or reinforced in classroom science programs; and (7) despite the students' involvement in science, most had little or no contact with real-life scientists. Recent national and international assessments of science education have indicated that students' home environments and personal learning environments are sometimes more closely linked to their science performance than the type of classroom science instruction the students have experienced. Findings from studies such as the present one can help us to fine-tune the way we conceptualize and measure the relevant nonschool contexts for pupils' science learning. Another reason that studies such as this are significant is that they suggest directions for improving classroom science programs. The author describes a cooperative effort to apply this investigation's findings in the school district in which the study occurred.

FURTHER DEVELOPMENT OF AN ELEMENTARY SCIENCE TEACHING EFFICACY BELIEF INSTRUMENT: A PRESERVICE ELEMENTARY TEACHER SCALE

Larry G. Enochs
Kansas State University
Manhatten, KS 66506

Iris M. Riggs
California State University
San Bernardino, CA 92407

The Science Teaching Efficacy Belief Instrument (STEBI) was revised to measure the beliefs of elementary preservice, rather than inservice, teachers. Based upon Bandura's social learning theory, the two sub-scales of STEBI (Form B) measure constructs of self-efficacy and outcome expectancy with regard to science teaching and learning.

Item and factor analyses revealed results consistent with previous research. The scales are homogeneous and distinct.

The STEBI (Form B) should be helpful in future investigations of elementary preservice training. Behavior is based upon beliefs. If elementary science education is to be improved, elementary teachers must be willing to devote more time and energy to this curriculum. Increased self-efficacy and outcome expectancy beliefs are predicted antecedents to this behavior change.

ATTITUDE AND SECONDARY SCHOOL SCIENCE STUDENTS' INTENTION TO ENROLL IN PHYSICS: AN APPLICATION OF THE THEORY OF PLANNED BEHAVIOR

Frank E. Crawley
Carolyn B. Black
University of Texas at Austin
Austin, TX 78712

The purpose of this attitude study was to explore the utility of the Theory of Planned Behavior for understanding and predicting the behavioral intentions of secondary science students in the selection of science courses the following year. In particular, the study investigated the relationships between beliefs, attitudes, social support and environmental pressures on the specific behavioral intention of 261 students (grades 8-12) to enroll in a high school physics course.

Data were collected from secondary science students in a central Texas city enrolled in earth science (8th grade), biology (9th or 10th grade), physical science (10th grade) or chemistry 1 (10th or 11th grade). Behavioral intention, attitude toward the behavior, subjective norm, and perceived behavioral control were analyzed by simple and multiple regression methods.

Results of this study indicated that the students' intention to enroll in a high school physics course, the target behavior, was dependent upon the students' attitude toward the behavior [AB] in all grades except eleventh, (grade 8, p=.0001; grade 9, p=.0055; grade 10, p=.0001; grade 11, n.s.) Perceived behavioral control [PBC] was a significant contribution at all grades except eighth (grade 8, n.s.; grade 9, p=.0021; grade 10, p=.0025; grade 11, p=.0032). The only grade at which the influence of others [SN] was found to be significant was in the eleventh grade (p=.0445).

USING SCIENCE ACTIVITIES TO INTERNALIZE LOCUS OF CONTROL AND INFLUENCE ATTITUDES TOWARDS SCIENCE

Paul McD Rowland
Northern Arizona University
Flagstaff, AZ 86011

For more than a decade, science educators have accepted and repeated the notion that experiences with science activities that emphasize cause-and-effect relationships lead to an internalization of locus of control. Although the claim appears to be based on logical inferences, there has been no empirical evidence presented from a classroom setting that clearly supports the claim.

The purpose of this research was to determine the effect of weekly science activities designed to emphasize cause-and-effect relationships on internalization of locus of control. In addition, because previous findings have shown a correlation between locus of control and attitudes towards science, the research was also designed to investigate the influence of these activities on those attitudes.

Roughly equivalent intact science classrooms from grades seven through ten were assigned to control and treatment groups. In the treatment classes, weekly science activities that emphasized cause-and-effect relationships through questioning and graphing were provided to the students. In the control classrooms the existing curriculum was taught. Pretests and posttests were administered to measure locus of control using a modification of the Test of Science Related Attitudes consisting of four subscales.

Multivariate analysis of covariance of locus of control showed a significant interaction of grade and treatment. Follow-up analyses of covariance by grade showed support for the claim that the treatment increased internality of locus of control for eighth grade students but also revealed that the gain in internalization at the ninth grade level was greater for the control group. No effects were found for seventh or tenth grade students. Differences in teacher experience and/or classroom management problems may account for these results and may indicate the need to better prepare teachers for meeting the goals of increasing internalization.

Three of the attitude subscales (Society and Science, Normality of Scientists, and Inquiry) increased significantly as a result of the science activities. Enjoyment of science classes did not change significantly for either control or treatment groups.

The results for attitude toward inquiry are especially interesting because the scale is based on a common goal in science education, i.e. to develop a tendency to use inquiry methods. The reliability of the subscale (alpha = .73 pretest and .78 posttest) was sufficient to accept it as a reasonable measure of the subjects' intent to engage in inquiry behavior. As such, it fits well with the Ajzen and Fishbein Theory of Reasoned Action and, along with locus of control, may contribute to our understanding of the relationship proposed by Ajzen and Madden linking attitudes with perceived behavioral control.

A STUDY OF SELF-EFFICACY, ANXIETY, AND SCIENCE KNOWLEDGE IN PRESERVICE ELEMENTARY TEACHERS

Charlene M. Czerniak
The University of Toledo
Toledo, OH 43606

As our nation begins the phase of implementing the school reform reports of the early 1980s, it is important to remember that the professional training of teachers remains central to the success of improving school science programs. In spite of great national attention, many problems still exist in elementary school science. Elementary teachers often avoid teaching science, rely heavily on the use of the textbook, and express the concern that they were inadequately prepared to teach science.

Researchers attempting to identify factors related to these problems have studied teacher education, school organization, and teacher personality factors, among other things. Personality factors including sense of self-efficacy to teach science and anxiety toward teaching science seem to be viable constructs for examining and improving elementary science teacher education. These constructs have been found to be associated with attitudes toward teaching science, type of science instruction used, success in science courses, confidence to teach science, and amount of attention given science instruction in the elementary school.

Predictors of science teaching anxiety and science teaching efficacy, however, remain elusive or tenuous. In addition, few methods have been implemented to try to improve science teaching efficacy and lower anxiety toward science teaching. Therefore, this study was designed to examine possible factors affecting science teaching anxiety and science teaching efficacy in preservice elementary teachers and two possible times when science teaching efficacy and anxiety might be changed.

This study took its sample from undergraduate students enrolled in a required elementary science methods course. The course is designed such that students spend 2.5 hours a day for the first five weeks on campus and 2.5 hours a day the second five weeks in field-based experiences where they implement a science unit. Approximately 45 students each quarter were sampled for this study.

The factors examined in this study included college GPA, score on a state wide assessment of science knowledge from grades 1-8, science teaching anxiety score, and science teaching efficacy score. The anxiety and efficacy scales were administered at three different time intervals, before the start of a required undergraduate science methods course, after the first five weeks of the methods course when the campus-based portion was completed, and at the completion of the second five weeks of the quarter when the field-based portion of the science methods course was completed.

Science Teaching Anxiety was measured by adapting the directions of the State-Trait Anxiety Inventory (STAI) so that preservice teachers responded to their anxiety about teaching science with their present knowledge and skill. Science Teaching Efficacy was measured by altering the Gibson Teacher Efficacy Scale so that items questioned teachers about science teaching rather than just teaching in general. College GPA was obtained from student records, and science knowledge was measured with the State Wide Assessment: Science Grade 8.

Symposium

RESEARCH ON SUSTAINING AUTHENTIC SCIENCE IN ELEMENTARY SCHOOLS

Ronald D. Anderson
University of Colorado
Boulder, CO 80309

James Gallagher
Michigan State University
E. Lansing, MI 48824

Carole P. Mitchener
University of Missouri
St. Louis, MO 63121

Kenneth Tobin
Florida State University
Tallahassee, FL 32306

Deborah Muscella
Biological Sciences Curriculum Study
Colorado Springs, CO 80903

Authentic hands-on, minds-on science instruction in elementary schools is not widely practiced. Programmatic attempts to initiate it often start with apparent enthusiasm and considerable investment in equipment and materials, only to gradually slide into disuse and a return to the old ways of doing -- or not doing -- it.

This symposium is focused on research which deals with this situation and identifies potential means of improving this situation. Research will be discussed which addresses the question of how to sustain authentic science instruction at the classroom, school and district levels.

The five presenters on this symposium have each conducted research related to this issue. Working independently in different parts of the U.S., but with consultation with each other about their research, they have used qualitative methods to study instances of successfully implemented and sustained elementary science programs at the school or district level, successful individual teachers, or specific programs for changing the approaches of teachers.

The symposium will include a brief presentation by each person of his or her research followed by discussion of such questions as the following:

1. What are the barriers to authentic elementary school science instruction?

2. What actions at the teacher, school or district level are effective in sustaining authentic elementary school science?

3. How authentic is the science instruction resulting from new programs?

4. What further research would be useful in this arena?

REPRESENTATION AND FEEDBACK IN THE FORMATION OF A CHEMICAL CONCEPT

Patricia Iuele
Rutgers University
New Brunswick, NJ 08903

This paper describes research on the organization and representation of knowledge as well as accommodation of new knowledge of a physical science concept. The following questions are proposed for study:

1. To what degree is there evidence of restructuring?
2. How do the subjects use the observed experiments as feedback to change the theory?
3. In predictions, what level and type of failure occurs?
4. Does an increase in complexity result in a regression in reasoning?

The procedure used in this project involved subjects in a "DOE" - demonstrate, observe and explain-protocol. During the protocol a series of related experiments which begins with a familiar situation and proceeds to less familiar situations is observed and explained. The phenomenon studied was the boiling of a variety of liquids under different conditions. This phenomenon was chosen because it is very often experienced but requires an understanding of the molecular interactions and fundamental forces involved if less familiar situations are to be predicted and/or explained. Because it creates new and extended environments, the sequence allows the subject to restructure the problem and expand his representation of the problem. The original responses and the changes in their responses provide information that allows us to infer about the internal organization, representation and means of accomodation of the involved subjects.

The subjects were students enrolled in a graduate level science education course at the time of the protocol.

Preliminary analysis of the responses of the subjects indicate that although they are familiar with the macroscopic phenomena, there is little foundation in a molecular representation. Most subjects avoided using a molecular representation in their explanation. Those who did use a molecular representation usually demonstrated a lack of understanding of the scientific meaning of the words or a misunderstanding of when a particular law was applicable. Predictions were usually based on a pattern they tried to detect in the experimental design rather than on theoretical relationships. As the situations became more complex, many subjects ignored the observations and explanations that they had given in a simpler situation even though the explanations were correct in the previous experiment and still applicable. Some would cite relationships but then use an opposite to make a prediction.

Those who were most successful in predicting the correct observations or using experimental feedback to explain why they were wrong generally had a better molecular representation in place or considered molecular level questions during the analysis.

METACOGNITIVE BEHAVIOR OF NOVICE BIOLOGY STUDENTS

Lavinia Kumar
Rutgers University
New Brunswick, NJ 08903

A two part study was undertaken to focus on learning strategies during review of a college Introduction to Biology lecture material, whilst using an interactive videodisc system.

The first stage included assessment of possible conceptual change, obtained by using pre- and post-tests immediately before and after the tutorial, by audiotaping groups of two or three during utilization of the tutorial, and by requiring the students to fill out a questionnaire after the tutorial was terminated. Learning strategies were qualitatively assessed by listening to the tapes.

In the second study, assessment of learning strategy was more directly obtained by pre-testing, during which the student was asked to assess (and thus be sensitive to) his/her state of knowledge; the time spent on each frame or page of the subsequent tutorial was then recorded by the authoring system. The pre-test answer to a concept was related to time spent on the relevant tutorial frames or pages.

It was found that the concept development was fragile and therefore changeable, as has been seen in the literature; but that (at least in the cooperative groups) learning was ongoing, even if some concepts reverted to prior levels. However, no learning strategy was evident either in group study or with individuals. Thus, it was apparent that directing a student to a learning path may be necessary, but not sufficient, for learning (as opposed to simply memorizing new concepts). Multiple exposures to new concepts may be necessary, especially at college age, where prior conceptions abound.

In the second study it was found that students with low prior knowledge of concepts tend to spend less time on frames related to that concept. There is some indication that this may change if the related video is a movie. Students past the completely novice stage appear to spend more time. Motivation and affective considerations thus form part of the metacognitive strategy.

The interactive videodisc may be a very useful tool in beginning biology, in that for proper conceptual development, both the verbal and visual information must be combined for proper representation. However, the student must be guided in this, concept tasks, and time on those tasks.

COMPUTER TECHNOLOGY: THE DYNAMIC PROBLEM PRESENTATION INTERFACED WITH THREE INSTRUCTIONAL MODES

Sheila Pirkle
Jeffrey Correll
Louisiana State Department of Education
Baton Rouge, LA 70804

An experiment was conducted comparing three groups of ten eighth grade students' performances in mastering the concept of projectile motion in a gravitational field. The computer program called the "Flight Protocol" was used as the mechanism for dynamically presenting the projectile problems to the subjects. The "Flight Protocol" was varied using three procedures, named Version I, II, and III. Each involved a specific variation of instructional intervention: limited interaction, cognitive modeling, and probing questions. Qualitative analysis of the subjects' responses to the Flight Protocol revealed the relative effectiveness of the use of probing questions or cognitive modeling, when compared with the responses to the limited intervention strategy.

SIMULATION AND STUDENT REPRESENTATION IN SOLVING KINEMATICS PROBLEMS

Alan Naimoli
George Pallrand
Rutgers University
New Brunswick, NJ 08903

Investigating how high school students represent, organize, and reason through simple physics problems can provide insight as to pedagogic considerations necessary for rich and meaningful problem solving experiences. Such experiences should provide a foundation upon which a high school physics student can extend and restructure previous knowledge representations that are later generalized to more novel problems.

The primary purpose of this study was to investigate how 16-18 year old high school students represent, organize, and reason through simple problems in kinematics. Of primary interest was the extent to which self-referential, metacognitive behaviors are used to interact with a computer simulation of a simple kinematics problem sequence to modify previous knowledge representations.

The following questions were proposed for study:

1. To what extent does a self-referential, metacognitive problem style enable a learner to productively work through solutions to simple kinematics problems?
2. To what extent is a computer simulation used to modify initial representations of projectile motion consisting of a vertical and horizontal component?
3. How and to what extent are initial representations altered while working through a problem sequence on projectile motion?
4. To what extent does the successful completion of an introductory high school physics course influence problem solving behaviors when working through simple kinematics problems?

Public high school male and female students completing their junior or senior year were used in this study. Students were divided into one group who had completed an introductory high school physics course and another group who had not.

This study utilized a computer simulation of a projectile being shot from a cliff in increasingly complex situations. Interviews of each subject followed a prescribed Flight Protocol.

FEEDBACK: A MECHANISM IN MODELING COGNITION

Frank Gagliardi
Rutgers University
New Brunswick, NJ 08903

Tasks in such disciplines as physics and mathematics are more often than not regarded as difficult and complex. It can be conjectured that this situation may emanate from the highly ordered and algorithmic presentation of the formalisms often associated with the pedagogy of their subject matter. Formalistic presentation is often expressed with the focus being directed to its correctness, with little or no regard for the conceptualization of the phenomena. It is essential that sound pedagogical practice be cognizant of the type of knowledge structures being developed in conceptualization.

Knowledge representation and its development has always been recognized as a central issue in any research involving an understanding of the cognitive processes employed by humans in performing a task. Past criteria for identifying any particular notation to express the structure of a representation, or categorizing different knowledge structures that have been encoded to a specific notation seem to have been selected by semantic preference rather than process. However, it appears plausible to infer that different knowledge structures have different processes defined upon them. The basic assumption is that representations can be defined in terms of the processes that operate on them rather than the notation that expresses them.

GENDER, SCHOOL TYPE AND SCIENCE ACHIEVEMENT OF ELEMENTARY STUDENTS...ARE THEY RELATED?

Pamela Fraser-Abder
New York University
New York, NY 10003

The present study was designed to determine the empirical validity of the assumption that some linkages exist between gender and achievement in science at the elementary level. The 977 students who served as subjects were randomly selected from approximately 20,000 Trinidadian students who wrote the 11+ examination in March, 1989. They were spread between nine denominational and six government schools.

The results of t-test, Chi square, and the contingency coefficient indicate that the null hypothesis should be rejected, and that there is a significant association between student gender and science achievement and between school type and science achievement.

Data analyses for the relationship between school type, student gender, and science achievement score were all at the .001 level of significance. The results indicate that the girls in all girl schools achieve better than boys in single sex schools or students in co-educational schools.

Science educators and curriculum developers should take this interaction into account when developing learning materials, and teaching and learning opportunities for students at this level.

GENDER DIFFERENCES IN EXAMINATION TYPE PREFERENCES, TEST ANXIETY, AND ACADEMIC ACHIEVEMENTS IN COLLEGE SCIENCE EDUCATION - A CASE STUDY

Uri Zoller
David Ben-Chaim
Haifa University - Oranim
Kiryat Tivon, Israel 36910

We live in a test-conscious age in which the lives of many people are not only greatly influenced, but are also determined by their test performance. No wonder that most students in college conceive examination situations as threatening and experience an increase in state anxiety during (or just before the commencing of) tests, particularly in the natural science disciplines.

This study consists of a mission-oriented research project, the educational philosophy and rationale of which is that:

1. The existing inverse relation between anxiety and test achievements is contextually bound and exam-situation dependent and, therefore, a change in the test situation (i.e., relaxed atmosphere and compliance with student examination type preferences) should be reflected in lower anxiety and higher achievements in science courses; and
2. Since there is sufficient evidence to support the existence of gender differences in existing science and technology education, strategies toward gender equity should be taken within the day-by-day educational practice of science teaching.

The objectives of this study were twofold:

1. To assess the preferences of college students (specifically, prospective science teachers) concerning examination types in science courses and identify gender differences in this respect, if any.
2. To study the interactions between examination type, test anxiety, and academic achievements in relation to gender differences, within an attempt at reducing the test anxiety of the students--through the use of those kinds of examinations preferred by them--and thus, hopefully, to improve their performances accordingly.

The Hebrew version of S.H.M.T. of Spielberger's State-Trait Anxiety Inventory (STAI) and the TOPE questionnaire developed by us (Zoller & Ben-Chaim) have been utilized to assess students' trait/state (test) anxieties and their preferences concerning examination types in science courses respectively.

Our major findings are that:

1. Our students prefer by far the "nontraditional" examinations in which the emphasis is on understanding and analyzing, that the use of any relevant material during the examination be permitted, and that the time duration be practically unlimited (e.g., "take-home" type exams).
2. This preference is significantly higher by female compared with male students, whereas oral class examinations are the least preferred type.
3. Although no significant gender differences in the levels of trait anxiety have been found, the anxiety of males drops significantly more than that of females after the first year of study.
4. Test (state) anxiety of female students is higher than that of males in traditional class science exams and it drops substantially in both genders - to the trait anxiety levels-in "take home" examinations.
5. The reduction of anxiety correlates with better academic performance/achievement, significantly more for females than for male students.

We propose, therefore, that science teachers (and teachers in general) ask students about their preferences concerning examination types (as part of the existing testing-evaluation practices), and try to meet these preferences within their teaching strategies. This will enable students of both genders to actually demonstrate their real competence.

THE USE OF EMPIRICAL VERSUS SUBJECTIVE PROCEDURES FOR IDENTIFYING SCIENCE TEST ITEMS WHICH DISCRIMINATE AGAINST FEMALES OR MALES

Richard R. Tolman
Richard Sudweeks
Brigham Young University
Provo, UT 84602

The purpose of this study was to compare empirical and subjective procedures in identifying science test items which discriminate against males or females in a fifth grade population. Recently published techniques, such as the Mantel-Haenszel procedure, enable test developers to use both a priori and ex post facto procedures to identify specific items that may be functioning in gender bias.

The test used in this study was developed as an end-of-year, criterion-referenced instrument that was based on the standards and objectives in the Utah State Science Core Curriculum for the fifth grade. All items were multiple-choice; some utilized illustrations, but most were text only. The test was administered to approximately 700 fifth-grade students.

This paper reports the findings of the study in terms of a comparison of the two techniques employed. Items are compared that were identified as functioning differentially toward gender by either technique. Suggestions for the use of each technique are included, together with the characteristics of items that discriminate on the basis of gender.

THE EFFECTS OF AN INNOVATIVE ACTIVITY-CENTERED BIOLOGY PROGRAM ON ATTITUDE TOWARD SCIENCE TEACHING AMONG PRESERVICE ELEMENTARY TEACHERS

Donald A. Hall
St. Cloud State University
St. Cloud, MN 56301

This study investigated the effects of an innovative activity-centered biology program on attitude toward science teaching among preservice elementary teachers. Subjects were 159 students enrolled in a biology content course designed specifically for prospective elementary teachers. Pretest and posttest measures were taken from scores using the Revised Science Attitude Scale.

There were significant positive differences ($p<.001$) pretest-posttest following 10 weeks of instruction in attitude toward science teaching. In general, subjects in this study (1) thought science processes were important in the elementary classroom, (2) thought teaching science does not take too much time, (3) thought they would not dread teaching science, (4) hoped to be able to excite their students about science, and (5) thought children were curious about scientific matters. Subjects also apparently feared student questions about science they could not answer, feared science experiments would not turn out as expected, and did not think science would be a preferred subject to teach if given a choice.

It was suggested that factors such as inadequate science background, lack of specific training, high science anxiety, and failure to understand the nature of science could have contributed to some of the more negative feelings toward science teaching. Positive feelings could have been generated by the nature of the program itself, by employing specific strategies emphasizing concrete examples and live materials, and by providing built-in opportunities for student success. In addition, classroom climate, including small-group activities, social interaction, and positive student-teacher relationships could have contributed to favorable attitude toward science teaching.

The results of this study support the belief that the strategies and methods featured in the innovative science programs be incorporated into college science courses for elementary teachers. Since measuring preservice teachers' attitudes toward science and science teaching may not be adequate predictors of their actual science teaching behavior, longitudinal studies linking attitude and practice are recommended.

AFFECTING PRESERVICE ELEMENTARY TEACHERS' ATTITUDES TOWARD INQUIRY TEACHING IN SCIENCE THROUGH PROJECTS WITH INDIVIDUAL CHILDREN

Larry Flick
University of Oregon
Eugene, OR 97403

Preservice elementary teachers have positive attitudes toward and knowledge of science process skills. They score as well as preservice secondary teachers on tests of knowledge about process skills. These results contrast sharply with the well documented dearth of science instruction in the elementary grades. The purpose of this study was to improve attitudes toward learning science and inquiry-based science teaching through specially designed instruction in a science methods course for preservice teachers.

Eighty preservice teachers over two terms elected to complete one of two projects as part of their science methods course. The projects were considered different treatments for the purpose of this study. Each treatment involved conducting an in-depth, inquiry-oriented project with one child for the duration of the course. The DiS project used a science topic as the basis for discussions between teacher and child. The teachers analyzed children's thinking about science as well as variables affecting inquiry science teaching. The MP project used a topic jointly selected by a middle school "able learner" and the teacher based on a mutual interest. These topics were generally in the social sciences and the project focused on developing a presentation by the "able learner."

The Test of Science-Related Attitudes, and Preferences and Understandings were adapted to measure attitudes toward science and inquiry teaching. Paired t-tests of pretest and posttest gain scores showed a significant increase in attitudes toward inquiry teaching in the DiS project and not in the MP project. An analysis of covariance holding pretest attitudes constant failed to show a significant difference.

The result that the DiS activity competed on equal terms with a project centered activity mainly in the social sciences is examined in light of preservice teachers' perceptions of the purpose of science education. Other data from the study suggesting relationships between attitudes and age, sex, and science knowledge are considered in a discussion about future research.

THE INFLUENCE OF DIFFERENT INSTRUCTIONAL DESIGNS ON PRESERVICE ELEMENTARY TEACHERS

Yu-Jiing Shyu
Taiwan Provincial Taipei Teachers College
Taipei, Taiwan, Republic of China

The quality of science education in elementary schools is closely related to the teaching competency of elementary teachers, and teachers' teaching competency in science is determined by the experiences received in their

teacher training programs. Therefore, in order to improve the teaching abilities of elementary teachers, science curricula in teacher colleges must be relevant to those in elementary classrooms, and provide a model for the teaching of science.

The purpose of the study is to investigate the impact of two different instructional designs of chemistry course on prospective elementary teachers' science content achievement, science process skills, and the attitudes towards science and science teaching. Subjects involved in the study were students who took the general chemistry course in the Taiwan Provincial Taipei Teachers College during the 1988 academic year. The students were divided into two groups: an experimental group and a control group. Students in the experimental group received activity-oriented inquiry instructions, whereas students in the control group received traditional instructions. The treatment period was 20 weeks. Students' science achievement, science process skills, and attitudes towards science were measured before and after the treatment. Their attitudes toward science teaching were measured at the end of study.

The results of the study indicated that the experimental group and the control group were not significantly different in science content achievement, science attitudes, and attitudes towards science teaching. In the measure of science process skills, no significant differences were observed between the two groups with the multiple choice test. However, students in the experimental group performed significantly better than those in the control group when they were asked to design an experiment to study a given problem.

THINKING PROCESSES MODEL: EFFECT ON LOGICAL REASONING ABILITIES OF STUDENTS IN GRADES SIX THROUGH TWELVE

Betty L. Bitner
Southwest Missouri State University
Springfield, MO 65804

The purpose of this experimental study was to investigate the effect of an eclectic thinking processes model on the logical reasoning abilities of students in grades six through twelve. The relevant research literature reviewed included (a) the development of thinking processes, (b) formal operational reasoning modes as predictors of academic success and critical thinking, and (c) strategies for teaching thinking processes. The sample (N=270) consisted of students in grades six through twelve in two rural Arkansas consolidated school districts. Although the total enrollment K-12 differed in the two schools, both school districts were quite homogeneous in the following aspects: (a) the socioeconomic level, (b) standardized test scores, (c) inclusion of mainstreamed students in the samples, (d) curricula mandated by the Arkansas Education Standards of 1984, and (e) geographical region. The science and mathematics curriculum, as mandated by the Arkansas Education Standards of 1984, included a total of five courses (two courses in one discipline and three in the other discipline). The experimental school consisted of 159 students in grades six through twelve, whereas the control school had 111 students in the same grades. The Group Assessment of Logical Thinking (GALT) was administered to the sample as a post-test. The GALT measures six reasoning modes (i.e., conservation, proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, and combinatorial reasoning). Construct, criterion-related, and internal consistency reliabilities were established for the GALT. The teachers and administrators of the experimental school received two intensive week-long workshops on thinking processes model. The thinking processes model incorporated logical, critical, and creative thinking skills. A consultant presented the 1986 summer workshop, whereas core teachers in the experimental school provided the 1987 summer workshop. The format of the 1986 workshop included the following steps: (a) oral dissemination of the theories accompanied by research articles relevant to the theories and ways of applying the theories, (b) engagement of the participants in applying the theories in their subject-matter and grade level; and (c) feedback, reaction, and evaluation. The focus of the 1987 workshop was review of the thinking processes presented during the 1986 workshop and development of model lessons for the teachers' individual classrooms. These teachers were encouraged to infuse the thinking processes into the mandated curricula during the 1986-1987 school term and were expected to do so during the fall of 1987. The control school district neither participated in the two summer workshops nor was expected to infuse thinking processes into the mandated curricula. A .80 internal consistency reliability coefficient was found on the GALT using Cronbach's alpha. For both the experimental (n=159) and the control school (n=111), correlational reasoning followed by probabilistic reasoning was the most difficult. The experimental school performed significantly higher than the control school in controlling

variables, correlational reasoning, and the total GALT score. Classification of the students according to reasoning levels revealed that only 3% of the total sample performed at the formal operational reasoning level. The significant differences in controlling variables, correlational reasoning, and total GALT score in favor of the experimentsl school seems to indicate that the eclectic thinking processes model was effective. In particular, the significant difference in correlational reasoning performance should be noted since correlational reasoning has been identified as the most difficult by other researchers. It is recommended that the same approach be implemented with tighter control.

STUDENT THINKING IN ADVANCED PLACEMENT AND GENERAL BIOLOGY CLASSES

J. Hugh Baird
Brigham Young University
Provo, UT 84602

Jennifer Schuyler
American Fork High School
American Fork, UT

This study was a quasi-naturalistic investigation of student thinking in high school biology classes. A review of the literature suggests a direct relationship between teacher/student verbal interactions and students' thinking. In several recent reports of schooling, high school classrooms have been characterized as void of challenge, dull, and mindless. This study began a long range look at the extent of, and the kind of, teacher/student interactions which would provoke high level thinking in biology classrooms. Observational data from advanced placement and general biology classes of eleven teachers who taught both subjects were collected and studied for patterns and interactions in the two types of biology classes.

Although a high percentage of student and teacher talk focused upon the subject matter being studied, it was almost completely void of challenge. Most of the effort was on memorization of information and recall of it. There was little difference in the two types of classes although in the AP classes girls were less inclined to play a passive, gender-related role.

WHAT STUDENTS NEED AND DO TO BECOME SUCCESSFUL LEARNERS: AN INFORMATION-CONSTRUCTIVIST PERSPECTIVE OF SCHOOL LEARNING

Robert J. Stahl
Arizona State University
Tempe, AZ 85287-1911

The goal of science education is improving the quality and quantity of student knowledge, conceptions, orientations, and abilities in areas connected to science content, skills and methods. The more aligned curriculum and instruction are to what students need to be successful learners, then the greater the probability of their learning and the more successful the science education provided.

This paper describes a model of school learning which is an expansion of Carroll's model and which incorporates the research findings in cognition, learning, and thinking over the past three decades; describes the basic tenets of the information-constructivist perspective, including its major principles and concepts; describes the concepts of infoschemata and cognitive-beliefs within the information-constructivist view, especially as these are similar to and different from these constructs as they are viewed in science, math, and reading education; and describes these new concepts and principles in relation to the area of misconceptions as an example area where these models are appropriate.

This model, linked to an information-constructivist perspective of cognition and learning, asserts that all thinking, acting, and responding has an information base which learners both use and act upon to build schemata, to make decisions, to assign meaning, and to construct their own version of the world and self as they attempt to make sense of it. This model is compatible with what students need to be successful and provides a series of very practical powerful and significant concepts and principles for science educators to plan for, monitor, assess and guide student learning in all grade levels across all content areas. Direct applications of the model to the misconceptions, schemata, and teaching and perspective are learnable and are currently being used by pre- and in-service science teachers for planning and monitoring instruction.

AN ASSESSMENT OF WHAT GRADE 5 STUDENTS KNOW ABOUT SCIENCE TEXT AND SCIENCE READING

Larry D. Yore
Madge T. Craig
University of Victoria
Victoria, B.C. Canada V8W 2Y2

Reading comprehension of science text depends on the reader's prior conceptual knowledge of the science topic, prior knowledge about science text and science reading, and executive and strategic functions related to learning. The interactive-constructive model of learning illustrates the importance of the learner's cognitive and metacognitive abilities. Metacognition subsumes the self-appraisal and self-management of cognition. Self-appraisal of cognition includes declarative knowledge, procedural knowledge, and conditional knowledge. Self-management of cognition includes strategic planning, evaluation and regulation by the learners of their learning.

This study attempted to develop effective and time efficient assessment techniques for self-appraisal of science text and science reading and to assess middle grade students' metacognitive knowledge about science text and science reading. Standardized interviews, word associations, concept maps, and objective examinations were administered to grade 5 students in an interior school district of British Columbia. All 98 students completed one of two forms of the objective examination and either a parallel concept map or word association. A stratified sub-sample of 24 students was individually interviewed using standard protocols that paralleled the objective examination.

Data generated by these assessment techniques were compared and contrasted to establish validity. The objective examination was factor analyzed to confirm the validity of the metacognitive dimensions intended. Reliability of the objective examinations was determined for individual items and both forms of the assessment. The individual correlations of each item with the total score were used as indicators of item reliabilities. Internal consistency was determined as indicators of the alternative forms' reliability.

Preliminary results of the interviews reveal that grade 5 students have reasonable declarative, procedural, and conditional knowledge about science text and science reading but, on average, much growth is needed to become efficient, successful science readers. These results clearly identify metacognitive dimensions regarding science text and science reading that would be strengthened by explicit instruction designed to improve students' knowledge of the Whats, Hows, Whens and Whys of using science text and science reading. Reciprocal teaching was also identified as a promising instructional strategy that provides the supportive scaffolding required to acquire self-appraisal of science text and science reading.

INFLUENCING LEADERSHIP IN SEVENTH GRADE LIFE SCIENCE CLASSROOMS

Mary M. Atwater
David Butts
Patricia Simmons
University of Georgia
Athens, GA 30602

Rosalina Hairson
National Association of Biology Teachers
Reston, VA

The most critical player in teaching life science to middle and junior high school students is the teacher. The attitudes of southeastern students toward science classes have declined in 1981. In response to the decline in attitudes, a three year summer institute for middle school life science teachers was conducted. This study of the first year of the institute was designed to assess teachers' professional development and the relationship to their attitudes toward science and science teaching. Twenty-two middle and junior high school science teachers from the southeastern United States participated in a five-week summer institute. During the institute, the teachers participated in morning sessions on contemporary issues in biology. To assess participants' knowledge gains, they were required to generate a self-report listing science questions for upcoming topics and a self-report listing two science ideas which impressed them. At the conclusion of the institute, teachers reviewed the initial list of questions they generated and rated their personal scientific knowledge of the question. The afternoon sessions focused on pedagogical knowledge and skills (emphasizing laboratory applications) in middle school life science education.

A correlation between teachers' science questions and concepts listed and rated at the end of the institute revealed that the teachers expanded their knowledge in contemporary science topics on which they generated questions. A Chi square analysis of the pretest and posttest data revealed a significant difference in teachers' responses before and after the sessions. The teachers' responses on the posttest questionnaire exhibited positive gains.

Pretest and posttest assessments using the Survey of Opinions Toward Middle/Junior School Science Scale were administered to the teachers. A binomial test of the number of positive differences between the post-test and pre-test scores was done, since the distributions of differences between the pre-test and post-test scores do not conform to a normal distribution curve and do not satisfy the underlying assumptions for a t-test. The probability that the positive difference is greater than 13 is 0.048. Therefore, there was a statistically significant positive change in the attitudes of participants about life science and life science teaching.

THE EFFECTS OF AN EXTENDED CASE STUDY ON CITIZENSHIP BEHAVIOR AND ASSOCIATED VARIABLES IN FIFTH AND SIXTH GRADE STUDENTS

Patricia R. Simpson
St. Cloud State University
St. Cloud, MN 56301-4498

The purpose of this study was to assess the effects of an extended science-related social issue case study, which addresses each of four curricular goal levels, on the overt citizenship behavior of midwestern fifth and sixth grade students and the precursors associated with this behavior. The extended case study is an issue investigation and action training methodology which allows students to complete a teacher-directed investigation of a locally important issue, in this case, management of the Canada goose.

A modified nonequivalent control group design was used with fifteen intact fifth and sixth grade classes from Illinois and Tennessee. Nine of the classes received instruction with an extended case study (n=187) and six received typical elementary science instruction (n=116) over a period of about 11 weeks. Pretest data were collected on overt citizenship behavior. Analysis of these data did not reveal evidence of preexisting differences in the classes on this variable. Posttest data were collected on these five variables: (1) overt citizenship behavior, (2) individual locus of control, (3) group locus of control, (4) knowledge of citizenship behavior, and (5) perceived skill in the use of citizenship action skills.

Analysis of variance was used to compare treatment and control group means. Statistically significant differences were found in: (1) overt citizenship behavior ($F_{1,13}$=12.341, p=.0038), and (2) knowledge of citizenship action ($F_{1,13}$=19.071, p=.0001). Locus of control, both individual and group, and perceived skill in the use of citizenship action skills were not found to be statistically significant.

The experimental treatment was found to be more effective than the control treatment in improving citizenship behavior and knowledge of citizenship action in fifth and sixth grade students. Alternative hypotheses are presented to account for lack of statistical significance in the other variables under investigation. Research and educational recommendations are provided.

A PLANT IDENTIFICATION TASK - AVOIDANCE PATTERNS IN CHILDREN

Delena Tull
University of Texas
San Marcos, TX 78666

An ethnographic study was conducted with the goal of evaluating the botanical concepts of sixth grade students. One aspect of the study involved examining the levels of abstraction of students' names for plants. Nine sixth-grade students were interviewed individually. Each was asked

to identify plants examined in two outdoor sessions. Out of analysis of the data, avoidance patterns emerged which the researcher found worthy of reporting.

Berlin developed a model for analyzing the layman's concept of the hierarchical relationships of plants. This researcher used his model to analyze the levels of abstraction preferred by the informants in naming plants. In Berlin's model, the category "plant" would form the top of the hierarchy. The next level, the life-form class, typically includes categories such as "tree, bush, vine, grass." Below the life-form is the generic class, which includes such names as "oak, maple, ash." The specific class would include such names as "live oak" or "red oak" as types of oaks. "Live oak" is a less abstract name than "oak." "Oak" is less abstract than "tree."

All informants exhibited a preference for generic names rather than more abstract names for plants. As they frequently lacked acceptable generic names, however, informants were often forced to provide an alternate answer. Three avoidance patterns emerged when students lacked a correct generic name: avoidance of an abstract response, avoidance of admission of ignorance, and avoidance of being wrong.

Only four informants showed a marked tendency to avoid using abstract names (such as the life-forms "tree, bush") in their responses. To avoid giving an abstract response, the individual might use made-up generic names, descriptive phrases instead of names, or simply say "I don't know," or give no response.

For other informants, avoidance of a display of ignorance and/or avoidance of being wrong apparently outweighed their desire to avoid the more abstract levels of response. Informants used several methods to avoid admitting ignorance when they did not know the generic name: substituting a life-form name, using made-up generic names, or giving an educated guess.

To avoid admitting ignorance, however, a student must often risk giving a wrong answer. For some students, giving a wrong answer was their major concern. These students used various techniques to hide their lack of knowledge: substituting life-form names ("tree" rather than "oak"), providing a description rather than a name, or giving no response at all.

The results call for a re-evaluation of text and teacher expectations. The text should reflect the knowledge base and abilities of the child, emphasizing generic names for plants rather than the highly abstract classification scheme common to the elementary science text. Rather than discouraging students when they give "wrong" answers, teachers should encourage students to learn from their own mistakes.

READINESS TO LEARN COLLEGE PHYSICS

Arnold Paltzer
Nassau Community College
Garden City, NY 11530

College physics professors believe that it is important that students have certain personal attributes when they enter the college classroom if they are going to be successful in learning physics. However, the aim of most precollege physics curricula is to give students an exposure to the subject matter of physics rather than to promote their intellectual development in the most important ways for their future education. Thus, high school physics is found by some observers to be irrelevant to success in college physics. This cannot be remedied until it is determined which are the intellectual abilities most important to learning college physics. Identification of these abilities was the aim of this study.

College physics professors, both those primarily involved in research and those primarily involved in teaching, were asked to rate the importance to learning physics of different elemental intellectual abilities. These abilities were chosen from the 120 different elemental abilities in J. P. Guilford's Structure-of-Intellect model of intelligence. In this model every intellectual act can be described as one of five different processes acting on one of four different kinds of content to produce one of six different kinds of products. The instrument used here was a 65 item questionnaire. Each subject was asked to rate the importance of the intellectual ability described in each item as (1) irrelevant, (2) peripheral, (3) useful, (4) important, (5) very important, or (6) crucial to learning physics. Each questionnaire item consisted of a definition of the elemental ability and an example of how that ability might be useful in learning physics. Half of the subjects were asked to rate the items for students studying to be physicists and half for students studying physics with the aim of becoming scientifically aware laymen.

The data elicited were factor analyzed to determine the pattern of correlations into clusters or factors. The items most strongly associated with these factors were examined and the factors identified. It was found that the ratings grouped into four factors which were essentially independent of each other. One factor was comprised primarily of abilities relating to mathematical insight. Another consisted of visualization abilities. A third was identified as logical abilities. The fourth general factor was identified as the ability to attack problems in productive ways when many approaches are possible.

The ratings of these four general abilities, labeled Mathematics, Visualization, Logic, and Problem Solving, were compared for four subgroups of respondents. There was found to be no significant difference in the ratings of these factors for physics professors who identified themselves as primarily researchers when compared to the ratings of those who identified themselves as primarily teachers. Three of the four factors were believed to be more important for students studying to be physicists than for students studying to be scientifically aware laymen. This was especially pronounced for Mathematics. For both groups of students, Logic was rated as the most important ability. followed by mathematics.

This was a descriptive study of beliefs. A program of future experimental research is called for to see if the abilities identified here predict success in college physics and, if so, how these abilities can be cultivated in the student.

A COMPARATIVE STUDY OF TARGET AND NONTARGET STUDENTS

C. Thomas Gooding
Michelle M. Kephart
Mary A. Connery
J. Nathan Swift
Patricia R. Swift
Robert E. Schell
State University of New York at Oswego
Oswego, NY 13126

Student involvement in classroom activities is a major component of effective classrooms. A combination of factors contributes to the effectiveness, but interactions and discussions between teachers and students are essential. Unfortunately, not all students participate in instruction. Research indicates only a small percentage of students are selected by the teacher to participate or initiate interactions themselves. As a result, few students are actively engaged in classroom learning. Of all classroom process variables, the interactions between teachers and students might be expected to have a great effect on student outomes. This study compares the achievement and attitudes of highly involved students with uninvolved students.

Highly involved students, often called target students, are those students who participate as a consequence of being selected by the teacher and those students who actively participate in classroom interactions in a self-initiated manner. Target students have a significantly higher science achievement compared to nontarget students, but this does not necessarily mean their attitudes toward science class will also be higher. Previous research has not examined the attitudes of target students compared with the rest of the students. Sadker and Sadker (1985) stated that when students participate in classroom discussions, they hold more positive attitudes toward school and that positive attitude enhances learning. Since target students are highly involved in classroom interactions, their attitudes could be different from the attitudes of nontarget students.

The intent of this comparative study was to determine the achievement, attitudes, and perceptions of target and nontarget science students. Target students were identified from students' responses to a 10 item Target Student Involvement (TSI) Questionnaire and from the Teacher Questionnaire. The attitudes and perceptions about science classes of students were obtained from a 33-item survey. Following the identification of target students, their achievement, attitudes, and perceptions of science classes were compared to those of nontarget students.

A one-way analysis of variance (ANOVA) was used to test significant differences between target and nontarget students for each of the following variables: (a) TSI Questionnaire scores; (b) course grades; (c) New York State Regents grades; (d) highest level of education expected to complete; (e) science attitude, and perceptions of: (f) divergent thinking, (g) logical thinking, (h) student involvement, and (i) remembering information. Based upon the data, it was concluded that there is a significant difference in the TSI Questionnaire scores, course and Regents grades, science attitude, and perceptions of logical thinking and remembering information between target and nontarget students. However, no significant difference was found in the highest level of education expected to complete and perceptions of divergent thinking and student involvement. From these results, characteristics of a student highly involved in classroom interactions would include: high achievement, a positive attitude for the class, and recognition of the importance of logical thinking, rather than memory level information.

Target students appear to have higher achievement and a more positive attitude in science class compared to the other students. The works of other researchers supports the conclusion of this study that the number of students involved in classroom interactions should be expanded. When a teacher interacts with only a few students in the class, other students' engagement rates for classroom learning are lower. Researchers and teachers need to work together in order to find ways for all students to be actively engaged. Suggestions include changing whole class methods of instruction and utilizing alternatives to whole class settings.

ALTERNATIVE PHYSICAL SCIENCE CONCEPTIONS, SCIENCE ACHIEVEMENT AND FORMAL REASONING ABILITY OF STUDENTS IN GRADES EIGHT THROUGH TWELVE

Thomas G. Teates
George E. Glasson
Edgar D. Morris, Jr.
Virginia Polytechnic Institute & State University
Blacksburg, VA 24061-0313

Previous research has shown strong correlations between science background, reasoning ability, and alternative physical science conceptions for preservice and inservice teachers. The researchers in this study propose that similar correlations might be seen with secondary science students. Variables considered in the design of this research included student ability level, achievement, science preparation, formal reasoning ability, and alternative physical science conceptions. Results indicate distinct differences between the two populations sampled and further analyses of the data are in progress.

AN EVALUATIVE STUDY OF LEVEL ONE INSTRUCTIONAL VIDEODISC MATERIALS USED IN SCIENCE CLASSROOMS

Robert D. Sherwood
Ted S. Hasselbring
E. Jean Marsh
Peabody College of Vanderbilt University
Nashville, TN 37203

The overall objective of the study was to evaluate, in actual classroom environments, the use of level one videodiscs and associated materials. Specific questions of interest were;

1. Would the use of videodisc based materials provide "added value" to traditional classroom instruction?
2. How would teachers and students react to the use of the materials in classroom?

The use of optical based media in a variety of subject areas and grade levels has increased in the last few years as the cost of the media and hardware to use has decreased. Several different methods have been developed to use video materials. These have included direct instructional type vid o such as the ones that were used in this study. The effectiveness of these types of programs is of interest to administrators, teachers, and researchers and some evaluative studies have been done.

A school district in Eastern Tennessee was the partner in the reported study which was part of a longer two-year study of videodisc implementation in a school system. The school system was in a rural area and had two K-12 schools of approximately the same general type which were designated the experimental and control school respectively. Two different videodiscs were used in the experimental school; "Understanding Chemistry and Energy" and "Earth Science."

The control school teacher rated the questions on the chemistry videodisc posttest used with biology and physical science students as to their correlation to the topics that the teacher would have covered in the control classroom. Questions of different ratings were combined and an analysis of covariance was undertaken on these data. Statistically significant results were found for students in both biology and physical science classes favoring the group that had used the videodisc.

A less controlled study was carried out on the use of the earth science disc with results showing that students increased their knowledge in this area through the use of the video materials. Interview data collected from both students and teachers indicated very positive attitudes toward the use of both the chemistry and earth science materials.

THE VALIDATION OF THE PHYSICAL SCIENCE MISCONCEPTIONS TEST

Hsiung Tung-Hsing
Joseph P. Riley
University of Georgia
Athens, GA 30602

It is apparent from the literature of misconception research that a goal of science education should be not only to teach scientific knowledge, but to design instruction so that students abandon previously-held misconceptions and construct more valid conceptions in their place. It is also clear that problems with misconceptions begin as early as elementary school and are not restricted to students. The first step in altering misconceptions in science is identify what misconceptions the learner may hold. To identify physical science misconceptions among preservice teachers, a paper and pencil, two-tier multiple choice format instrument (PSMT) was developed.

This study describes the procedures to determine the construct validity of the PSMT by examining the relationship between results of the paper and pencil test and an interview test. The two formats of the tests differ only in method of administration.

Preliminary analysis of the data indicate a high correlation between responses on the paper and pencil test and open ended responses. The results suggest that the two-tier test has advantages over the interview, especially for teachers who are interested in diagnosing student misconceptions but have little time for interviews. The study has psychometric implications for the development and analysis of misconception testing as well as instructional use of the results of such a two-tier format test.

Symposium

ROLE OF THE EPISTEMIC SUBJECT IN PIAGET'S GENETIC EPISTEMOLOGY AND ITS IMPORTANCE FOR SCIENCE EDUCATION

Mansoor Niaz
Universidad de Oriente (Venezuela)
Estado Sucre, Venezuela

Anton E. Lawson
Arizona State University
Tempe, AZ 85287

Richard F. Kitchener
Colorado State University
Fort Collins, CO 80523

Joseph Novak
Cornell University
Ithaca, NY 14853

According to Piaget, a fundamental epistemological distinction must be made between the psychological and the epistemic subjects. The epistemic subject is studied by the genetic epistemologist who charts development through a "common universal rationality, which develops," whereas the psychological subject is studied by the developmental/cognitive psychologist by focusing on accidental contingencies surrounding particular people and their individual differences. The epistemic subject as compared to the psychological subject is an idealized abstraction, viz., that set of underlying epistemic structures common to everyone at the same level of development. The objective of this study is to investigate the degree to which investigators in science education conceptualize the difference between the epistemic and the psychological subjects. It is argued that just as the Ideal Gas Law (based on the theoretical formulation of Maxwell and Boltzmann) provides a "general model" to which the real gases approximate under different experimental conditions, so we can consider (by abduction) the epistemic subject to be an "ideal knower" to which the real (psychological) subjects approximate to varying degrees. The difference between the epistemic and the psychological subjects, however, cannot be used as an "epistemological shield" in defense of Piagetian theory. Any test of the Piagetian theory must involve psychological or real subjects.

Research conducted in science education shows that, at least for some critics, the wide variations in the age at which individuals acquire the different Piagetian stages, is crucial for rejecting the theory. It is argued that the real issue is not the "proportion of heterogeneity" but the understanding that Piaget by neglecting individual differences attempts to build a "general model" applicable across types of situations/subjects.

The distinction between the epistemic and the psychological subjects is important not for defending Piaget's theory (which has serious theoretical flaws) but to understand epistemic transitions, for example, the one between Piaget's epistemic subject and Pascual-Leone's metasubject. It is concluded that the failure to understand the distinction between the epistemic and the psychological subjects would be to misconstrue the significance of our research findings and, what is more serious, lead to a lack of a historical perspective.

SCIENCE TEACHING AND LEARNING: USING CONCEPT MAPPING TO DEVELOP REFLECTIVE PRACTITIONERS

Cheryl L. Mason
San Diego State University
San Diego, CA 92182-0139

A great concern exists that science teachers are modeling their own educational experiences by presenting scientific facts in a linear, disconnected manner either through lectures or cookbook laboratories. This is the type of approach which has turned most students off to the study of science and has led to our continued failure to produce a critical mass of scientifically literate individuals. In order to break into this cycle, teacher educators need to employ strategies which will encourage potential science teachers to reflect upon their own knowledge base of science teaching and learning and to realize the need to do so.

This two-year study investigated the effectiveness of various strategies used in two specially-designed teacher preparation courses. The particular strategy outlined in this paper is the use of concept mapping. This tool was used to assist potential teachers in their efforts to rethink and reorganize their conceptual knowledge of science in order to better comprehend the interconnectedness and robust nature of scientific concepts. In addition, the use of concept maps as a tool for evaluating the effectiveness of presentations, identifying misconceptions and developing critical thinking skills was evaluated. The underlying objectives for the concept mapping exercises were to help potential teachers realize:

1. the interconnectedness and hierarchy of scientific concepts;
2. that the concepts can be developed from a variety of perspectives (there is no such thing as an incorrect map as long as the relationships among concepts are accurate);
3. what they are presenting as teachers is not necessarily what the students are learning;
4. concept maps can be used to identify prior knowledge and misconceptions in both teachers and students;
5. explanation of concept maps reveals the difference between learning scientific concepts and learning scientific terms;
6. individuals have different learning styles and interests;
7. schema can be restructured by fitting networks of information together;
8. that students of science need to learn how to ask the questions and not just memorize the answers;
9. how the concepts of sience are related to the concepts of other disciplines; and
10. that, without prior instruction, they couldn't just send students to the text to gain meaningful information.

The use of concept mapping as a pictorial representation of memory structures or schema was shown to be an effective tool in teacher preparation courses. As time progressed the potential teachers began to develop less linear and fact-oriented maps and began to produce maps which demonstrated the interconnectedness of scientific concepts. The maps and subsequent explanations of the maps indicated that course participants were beginning to structurally integrate information that had previously been presented to them in a segregated fashion.

The changing of perspectives of the nature of science, and the teaching and learning of science content cannot occur totally within the brief time spent in these courses. However, subsequent interviews with subjects involved in this study indicated that they continued to be sensitive to the need for conceptually addressing the discipine of science and recognizing that students construct their own knowledge on the basis of their own schema.

COOPERATIVE LEARNING IN A COLLEGE SCIENCE COURSE FOR PRESERVICE ELEMENTARY TEACHERS

Diana C. Rice
Dorothy Gabel
Indiana University
Bloomington, IN 47405

In recent years, studies have indicated that science and mathematics achievement scores of students in the United States have been falling and interest in science and science-related careers has been declining. These factors have combined with the perceived threat to the economic superiority of the U.S. from other nations to spark renewed interest in science and math education. These conditions have led to increased efforts in the area of development, evaluation, and implementation of new methods of instruction, one of which is cooperative learning. Though used widely and studied extensively at the elementary and secondary level, few researchers have examined the use of cooperative learning at the college level, particularly in science.

The effects of cooperative learning techniques in a college science course for preservice elementary teachers were examined by comparing two classes taught by a more conventional laboratory technique with two classes taught utilizing cooperative learning techniques. Two teachers, each teaching one comparison class and one cooperative class, implemented the treatments. A final sample of 89 students provided data for analysis. The design for the study, carried out over a period of one semester, was a non-equivalent comparison group design.

Science achievement, development of laboratory practical skills, understanding of specific science concepts, change in attitude toward science and science teaching, and change in science comfort level were assessed. Achievement measures, laboratory practicals, and concept tests were analyzed using two-way and three-way analyses of covariance. Pre-

and post-scores on the Science Attitude Survey were analyzed as repeated measures in the assessment of affective variables. Main effects due to treatment and interactions between treatment and reasoning ability level, learning mode preference, and comfort level were examined in assessment of hypotheses.

Treatments were randomly assigned to classes. In the cooperative classes, cooperative learning methods were based in large part upon those described by Johnson & Johnson and to some extent by Slavin. Students were assigned to four-member heterogeneous teams based upon GPA. Teams turned in group lab reports for which all members received the team grade. Further, teams accumulated bonus points based upon improvement of team members on course quizzes. A major component of the cooperative method involved the assignment of cooperative team roles to each team member. The comparison classes were taught using traditional laboratory methods. Four students sat at each lab table. Students worked in pairs to facilitate efficient use of equipment and materials; however, no interaction beyond collection of data was encouraged. All laboratory reports were completed individually and students earned bonus points on quizzes based upon individual performance.

No significant differences were found relative to the main effects and interactions involving the variables of interest: treatment; reasoning ability level; initial science comfort level; and learning mode preference. However, other findings of interest should be noted. Not surprisingly, students who were of higher reasoning ability level scored significantly higher on the achievement variable. Also, all students in the course, regardless of treatment, demonstrated significant improvement in comfort level relevant to science. A significant teacher effect and teacher-treatment interaction was found on the laboratory practical scores. These effects may have been related to the mismatch between learning preference and testing methods.

COMPARISON OF A HANDS-ON WITH A REMEDIATION-BASED APPROACH TO TEACHING A COMMUNITY COLLEGE BIOLOGY PREPARATORY COURSE

Carol A. Biermann
Gary B. Sarinsky
Kingsborough Community College, City University of New York
Brooklyn, NY 11235

A biology preparatory course at an urban community college was studied to determine which of two different curricula, one based upon laboratory hands-on experiences and the other based upon mathematics and reading remediation, had an effect on students' performance in follow-up biology courses. One-way analyses of variance were used to compare all groups. The two groups did not differ significantly from each other ($p < 0.05$) in biology preparatory grades, age, sex, birthplace, years in the United States, type of high school degree, freshman mathematics, reading, and writing skills scores, but they did differ from each other in follow-up biology course grades. Each biology preparatory group was compared with a control group of students who should have taken the preparatory course but did not. Analyses showed that only the hands-on biology preparatory group was significantly better in follow-up biology course grades when compared with the control group. In addition, a larger percentage (23.2%) of the hands-on preparatory group passed biology follow-up courses with a grade of C or better when compared with the remediation-based preparatory group (16.1%).

REPLACING TRADITIONAL SPECIMEN-BASED LAB PRACTICALS WITH PROJECTION SLIDE-BASED LAB PRACTICALS

Thomas R. Lord
Indiana University of Pennsylvania
Indiana, PA 15705

Evaluating the knowledge gained by college students from their weekly biology laboratory experience is generally carried out with one or two practical examinations during the semester. While measuring class experience, these tests are extremely time consuming to prepare and difficult to administer. In addition, the test setting is usually cluttered and distractive. Such conditions can lead to an inaccurate evaluation of the student's knowledge by the teacher.

As a substitute for the lab practical, a study was conducted using photographic-slide exams of the semester's lab investigations. The tests were administered at the end of the semester to three groups of fifty college undergraduates taking a non-majors biology course at a mid-sized eastern university. Two of these groups were also encouraged to photograph

aspects of their lab investigations each week. Slides for the photo exam were prepared from the photographs supplied by one of these populations. A fourth group of fifty students served as the control population and took a traditional style laboratory practical at semester's end.

The lab test scores for all groups were subjected to Analysis of Variance and Scheffe-Contrasting statistics. The results of this application revealed that, while the groups from which the slide photos were selected scored higher than the rest, no significant differences in scores were found between the other slide-tested groups and the traditional lab-tested group. This would suggest that slide-based practicals are as reliable a measure of student lab knowledge as are traditional specimen-based practicals.

THE EFFECTS OF A DIAGNOSTIC AND PRESCRIPTI TRUCTIONAL STRATEGY ON THE ACHIEVEMENT OF HIGH SCHC JDENTS LEARNING SCIENCE FROM TEXT

Pierce Farragher
University of Victoria
Victoria, B.C. V8W 2Y2

This project examined the effects of different types of feedback, confirmation of results, and diagnostic testing on learning from text aided by a diagnostic and prescriptive instructional strategy. The study attempted to provide information about the uses of feedback with common instructional materials.

It was expected that any manipulation requiring the students to review the instructions would facilitate learning. Instructional feedback which encourages students to review the instruction should enable students to perform better on a criterion test than those who had no feedback.

This project utilized an experimental research methodology. The subjects were 125 grade 9 science students randomly assigned from intact classes in the Canadian school system. Subjects were randomly assigned to one of five treatments which varied along a feedback complexity range. After pre-testing, subjects completed a self-paced text unit on Soil Ecology followed by a posttest and delayed retention test.

The work of researchers such as Rothkopf, Anderson et al., and others confirmed the instructional value of placing key questions in text. One explanation of these results is that the questions elicit a deep processing of the textual materials. Information processing researchers, (e.g., Eysenck) argue for levels or depth of processing to facilitate encoding the passage of information from short-term memory to long-term memory storage.

The project explored embedded questions in a text. The questions were designed to function mathemagenically and to operate diagnostically and prescriptively when error occurred.

The built-in check (effect of embedded questions) did not reveal a mathemagenic effect as was expected. The overall achievement difference between groups was not significant. The test main effect was significant with mean score favoring immediate and delayed posttest scores over pretest scores. No significant differences between treatment groups for time-on-task were observed.

METAMORPHOSIS, ADAPTATION, OR EVOLUTION?: A LONGITUDINAL INVESTIGATION OF PRESERVICE SCIENCE TEACHERS' INSTRUCTIONAL DECISIONS, CONCERNS, AND PERCEPTIONS

Julie Gess-Newsome
Norman G. Lederman
Oregon State University
Corvallis, OR 97331

Given the prominence of the microteaching course and the student teaching experience within science teacher education programs, it is disconcerting that the related and combined effects of such experiences have been virtually ignored.

The initial sample used in this longitudinal investigation was 17 preservice secondary science teachers enrolled in a microteaching course. A stratified random sample of six of these preservice teachers was "followed" into the immediately subsequent student teaching experience.

During the microteaching course, each preservice teacher was provided with three different modes of feedback: (1) verbal critique by peers and instructor following each of the four lessons presented, (2) formal written critique from the instructor, (3) videotape of each lesson and required written self critique. In addition, each preservice teacher completed an open ended questionnaire (at the start of the course and following each lesson) designed to assess the individual's perceptions of planning, the relative importance of specific instructional skills/behaviors, and instructional decision making. Those students "followed" into student teaching completed a similar questionnaire at the beginning of student teaching and following each of the 15 weeks of their field experience. These individuals were systematically observed, videotaped, and provided with written and oral feedback in the same manner as provided during the microteaching course. In addition, these student teachers attended a weekly seminar in which their videotapes and concerns about teaching were systematically discussed. All seminars were audiotaped for later analysis.

Four "rounds" of qualitative analyses were used to assess: (1) congruence among the concerns, perceptions, and decision making skills identified upon the completion of the microteaching course and those expressed upon first "immersion" into student teaching, (2) development and/or changes of the aforementioned perceptions, skills, concerns, during student teaching. This repetitive analytic process yielded a final list of 17 areas of concern which were grouped into "concerns for self" and "concerns for students."

Those concerns and perceptions evidenced during microteaching persisted during student teaching, along with five additional areas of concern. These additional concerns were related to clerical responsibilities, work load, student motivation, rapport, time constraints, and appropriate level of subject matter.

Comparisons between the data derived during microteaching with those collected during student teaching yielded several intriguing results. During microteaching, planning was viewed as a systematic, rational process beginning with objectives and concluding with a mental rehearsal. During student teaching, time constraints resulted in an inattention to objectives and planning was reduced to a hasty search for "teaching tricks" which quickly conveyed subject matter while maintaining student interest.

Although the subjects completed the microteaching course primarily with "concerns for self," they exhibited an immediate dominance of "concerns for students" upon entering student teaching. It is hypothesized that the much publicized developmental shift in preservice teachers' concerns from self to students is more likely an artifact of inherent differences between campus based and field based teaching situations.

THE EFFECT OF TWO MODES OF SENSORY INPUT ON CHILDREN'S RETENTION AND RECALL

Ann C. Howe
University of Maryland
College Park, MD 20742-1175

Ellen S. Vasu
North Carolina State University
Raleigh, NC 27695

The purposes of the experiment were: (1) to test the hypothesis that two modes of sensory input will lead to greater retention and recall than either mode by itself, (2) to confirm the superiority of visual over verbal (auditory) stimuli in chidren's retention and recall, and (3) to confirm a previous finding that children recall more information when responding in pictorial form than in verbal (oral) form.

First (n=66) and fourth (n=62) grade children were randomly assigned to four treatment groups as follows: Group 1: observe, image, draw; Group 2: observe, image, listen, draw; Group 3: observe, listen, image, describe; Group 4: listen, image, describe. Subjects were posttested one week later.

Analysis of tne drawing scores yielded significant main effects for grade level and treatment. Analysis of description scores yielded a significant main effect for treatment. Correlations between drawings at Times 1 and 2, between descriptions at Times 1 and 2, and between drawings and descriptions at Time 2 were significant in most cases. Drawings contained more information that did verbal descriptions. Results support the main hypothesis and confirm results obtained in previous experiments.

Implications for science teaching are discussed. The results show the importance of visual input in the instruction of primary children; children remember what they see better than what they hear. The results also show that children can represent more of what they know in drawing than in verbal form, a finding that has implications for testing as well as instruction in science and other subjects.

THE EFFECTS OF CAI AND HANDS-ON ACTIVITIES ON ELEMENTARY STUDENTS' ATTITUDES AND WEATHER KNOWLEDGE

Cathy Gardener
Patricia E. Simmons
University of Georgia
Athens, GA 30602

Computer-aided instruction (CAI) is designed for the teacher and student to experience more effective and efficient learning and teaching than with more "traditional" teaching methods. Teachers must be aware of the quality of available software and supplemental materials in order to utilize CAI to its maximum potential. The National Survey on Instructional Uses of School Computers indicated that only fourteen percent of elementary classes were using computers for science instruction in 1985, and that computer usage in these classes occurred on an occasional basis. This preliminary study was undertaken to determine if a combination of CAI with hands-on science activities would significantly enhance students' abilities in the cognitive and affective domains.

The study consisted of three treatments. Treatment One included a hands-on activities emphasis. A second treatment included the identical hands-on activities in combination with the Weatherschool program. Treatment Three did not contain either hands-on activities nor CAI, but employed more text-based learning. The study was conducted in five third grade classrooms. The same teacher gave instructions, administered tests, and worked with the students in learning centers. The school chosen for this study was a public school where children were randomly assigned to the classes. There were 47, 46, and 21 students in Treatments 1, 2, and 3, respectively. A pretest and posttest were administered to each student to assess any changes in affective and cognitive parameters.

Analysis of variance of the pretest scores for attitudes demonstrated no significant difference ($P = 0.5824$) among the treatment groups prior to instruction. Mean scores for both the attitude and conceptual tests increased significantly ($P = 0.0001$) from the pretest to posttest for Treatments 1 and 2. Analysis of variance of the posttest attitude scores differed significantly ($P > 0.0001$) among the three treatment groups. The mean number of positive responses per student for the hands-on activities with CAI ($x = 12.9$, $SE = +0.3$) were significantly higher ($P = 0.0001$) than for the control group ($x = 9.3$, $SE = +0.4$). Mean scores of the hands-on activities with and without the CAI differed only at the $P = 0.05$ level. Based on the results from this preliminary study, hands-on activities resulted in increased scores from pretest to posttest. When combining hands-on activities and CAI, the gains from pretest to posttest scores were significantly higher than gains with only hands-on treatment.

As computers become more available and accessible to elementary school teachers, the effective use of science software programs coupled with hands-on activities requires more attention through appropriate preservice and inservice programs. CAI is one tool which can be employed to achieve these goals of providing positive and stimulating learning environments to elementary school students.

SCIENTIFIC REASONING AND PROBLEM SOLVING SKILLS EXHIBITED BY STUDENTS USING COMPUTER SIMULATION PROGRAMS

Willis J. Horak
Virginia M. Horak
University of Arizona
Tucson, AZ 85721

This study investigated students' use of scientific reasoning and mathematical problem solving heuristics within computer simulations. Middle school and junior high school students were observed as they worked with computer programs requiring problem solving skills. Audiotapes and records of computer keystrokes were recorded for each student. These records were analyzed to identify any similarities and differences in approaches in students' selected strategies.

Historically, science educators have taught students content (factual knowledge) and then assumed that they would be able to transfer that knowledge to later, real-life situations. However, recently many educators have expressed concern about the ability of students to transfer content knowledge to problem solving situations. There are many science educators who stress that if we believe that students can transfer basic, content knowledge to other situations then that is where we should concentrate our instruction. However, if we believe that students' ability to transfer knowledge to new and different situations is limited, then we should focus our curriculum and teaching techniques on ways to facilitate this transfer. This study utilized the second belief and thus concentrated upon problem solving heuristics and scientific reasoning skills exhibited by students engaged in computer simulated situations.

There were three main computer programs utilized in this study. They were all public domain programs and thus are readily available to researchers desiring to utilize these programs for future research. The programs were "House Builder," "Select the Environment," and "Make It 21." "House Builder" requires students to collect data and analyze it to solve future problems. It is a non-competitive problem solving situation. "Select the Environment" requires students to devise solutions to an environmental problem where species of animals and plants are in danger of extinction. It is non-competitive yet requires players to solve a problem within a prescribed period of time. "Make It 21" is an adversary game where the computer is an expert player and the students try to select numbers of stones (either 2, 3, or 4) before the opponent makes a pile of 21 stones.

Analysis of the data revealed students do exhibit identifiable scientific thinking and problem solving skills when interacting with computer simulation programs. There were nine categories of heuristics identified by the researchers analyzing the results of this study. Type of program and make-up of student problem-solving groups were influential in determining the identified scientific and mathematical problem solving processes. Recommendations are made for future research in the area of computer education in science education.

INTERPRETING THE LEARNING CYCLE FROM A LANGUAGE LEARNING PERSPECTIVE

George E. Glasson
Rosary V. Lalik
Virginia Tech
Blacksburg, VA 24061-0313

The purpose of this study was to examine (1) the opportunities for students' conceptual development and language learning as science teachers implemented a language-oriented adaptation of the learning cycle model, (2) the conceptual changes that occurred for teachers who implemented this model, and (3) how students responded to the opportunities that the teachers provided. Three experienced teachers (an elementary, a middle school, and a high school teacher) were interviewed about their instructional beliefs, wrote descriptions of their educational philosophies, attended eight three-hour reflection sessions, and were videotaped as they each taught a typical science lesson and four additional lessons using a language oriented learning cycle model. Following each lesson, teachers analyzed their instruction and raised issues and concerns that became problematic for them. At the end of the year, teachers were again interviewed about their understandings of the model, their learning processes, and their concerns. Two major analytic procedures were used to analyze the data--categorical analysis and discrepant case analysis. From these analyses, assertions were developed and hierarchically organized into themes and presented as case studies.

In each case, the teachers' practices became more consistent with their conceptions expressed early in the year. Teachers used the learning cycle model as a framework for their instruction, focusing especially on those features which were consistent with their existing beliefs. It is important to note that the existing conceptions of the teachers were not in conflict with those implied by the model. Instructional planning and analyses served as an important opportunity for changing teacher practice, and throughout the year each of the teachers framed and reframed problems as they worked to reflect on their use of the model. A classroom environment characterized by dialogue and discussion contributed to students' appreciation for science instruction and their feelings of self-efficacy as science learners.

THE EFFECTS OF CONTROVERSIAL ISSUES ON THE LEVEL OF WRITTEN PROSE

Jon E. Pedersen
University of Nebraska
Lincoln, NE 68588-0355

The effects of cooperative controversy and individualistic learning frameworks were compared on achievement levels. Seventy-five high school chemistry students (10th, 11th, and 12th graders), were randomly assigned as intact classes. In all conditions, the students studied controversial

issues with materials representing both pro and con view . In the cooperative controvery condition, each small group was divided into two halves representing the pro and con sides. Each small group working in unison was to master the instructional materials and write a collaborative report. The group was divided into two-person teams. Teams were given materials which supported and rejected both sides of the issue studied. In the individualistic condition, the students were instructed to study alone, and not to interact with any other students in the class. All subjects participated in identical sequences.

The results indicate that the cooperative controversy condition was superior in achievement on the consensus paper written by both groups. In the cooperative controversy condition, student responses were of a higher level (analysis, synthesis, and evaluation), and supported the use of controversies in the classroom.

TLTG INTERACTIVE VIDEODISC PHYSICAL SCIENCE PROGRAM: RESULTS OF THE 1988-89 FIELD TEST

Dava C. Coleman
Texas Learning Technologies Group
Austin, TX 78767

Thomas R. Koballa, Jr.
Frank E. Crawley
University of Texas at Austin
Austin, TX 78712

Ninth- and tenth-grade students from 20 Texas school districts, two in Louisiana, and one each in Washington and Indiana were involved in the 1988-89 field test of the Texas Learning Technology Groups' Physical Science program. The program is a comprehensive physical science curriculum delivered by an interactive videodisc (IVD) system that adheres to the traditional format of the general education, high school physical science course--one semester each of introductory chemistry and physics. A quasi-experimental pretest post-test control group design was employed for simultaneously conducted achievement and interest studies, with data collected near the beginning and at the end of the fall (chemistry) semester and spring (physics) semester. Two instruction configurations of the program were evaluated. Teacher only (TO) classes were equipped with a single workstation, while teacher group (TG) classes employed multiple workstations for student groups. Due to the size of the potential database, data were collected from only one class period per site for a total of 24 classes. Control classes were selected from the same or neighboring school districts. Interactive video and control classes were matched as closely as possible for ability levels of the students and teacher experience.

The two measures of achievement outcome were a criterion-referenced, mastery assessment test prepared by an external test developer in concert with the TLTG staff and the Test of Integrated Process Skills II (TIPS II). Student aptitude data were also collected, as aptitude was expected to affect student post-program performance.

Student interest in enrolling in elective, high school chemistry and physics courses and subsequent IVD courses was measured using an instrument based on Ajzen's Theory of Planned Behavior. From the theory, four variables were specified as the outcomes of interest: intention to perform a specific behavior, attitude toward a specific behavior, social support, and environmental control.

Students in the IVD classrooms significantly ($p < .0001$) outperformed the students in the control classrooms on mastery of physical science concepts and attainment of science process skills over the full range of student aptitude. Furthermore, no significant differences were detected between the TO and TG instructional configurations on the two achievement measures for either the fall (chemistry) or spring (physics) semester. During the fall (chemistry) semester, instructional configuration (TO, TG, and control) did not impact intention toward enrolling in an elective, high school chemistry course, attitude toward enrolling in such a course, social support for enrolling in such a course, or resources and opportunities for doing so. Likewise, student interest as measured by the four model variables was not affected by instructional configuration during the spring (physics) semester. Only during the chemistry semester was a significant ($p < .01$) difference detected between TO and TG classrooms on one interest variable, intention to enroll in subsequent IVD courses.

FURTHER VALIDATION OF A PRESERVICE ELEMENTARY SCIENCE EFFICACY BELIEF INSTRUMENT: THE CONTRIBUTION OF PUPIL CONTROL IDEOLOGY

Larry G. Enochs
Larry C. Scharmann
Kansas State University
Center for Science Education
Manhattan, KS 66506

Iris Riggs
California State University
San Bernardino, CA 92407

This study was designed to further validate the Riggs Science Teaching Efficacy Belief Instrument Form B (STEBI B) which was designed to measure the science teaching self efficacy of elementary preservice teachers. This study was designed to provide a valid and reliable measure of teacher self efficacy in preservice elementary teachers.

In order to accomplish this, the Riggs Science Teaching Efficacy Belief Instrument Form A (STEBI A) was modified from an inservice orientation to that of preservice. This instrument consisted of two subscales that were consistent with the theory suggested by Gibson and Dembo. The subscales were entitled Personal Science Teaching Efficacy Belief Scale and Science Teaching Outcome Expectancy Scale. The purpose of this study was to determine the hypothesized relationship between pupil control ideology and science teaching efficacy.

The Pupil Control Ideology scale, developed by Willower et al., was used to assess teachers' control ideology. The STEBI B was used to measure both outcome expectency personal science teaching efficacy. Preservice elementary majors (n=73) were used as subjects in this study. The following research questions were addressed in this study:

1. Is there a significant relationship between preservice elementary teachers' Personal Science Teaching Self Efficacy and their Pupil Control Ideology?
2. Is there a significant relationship between preservice elementary teachers' Outcome Expectancy and their Pupil Control Ideology?
3. Are there significant relationships between other factors such as time spent teaching science, choice of teaching science, and perceived effectiveness in teaching science and Personal Science Teaching Efficacy, Outcome Expectancy, and Pupil Control Ideology?

Pearson product moment correlations were used to analyze the data. In addition, Cronbach's alpha coefficient and factor analysis were used to assess the reliability and validity of the PSTEB, STOE, and PCI.

THE EFFECTS OF HANDS-ON SCIENCE INSTRUCTION ON PRESERVICE ELEMENTARY TEACHERS' COGNITIVE STRUCTURES AS MEASURED BY CONCEPT MAPS

Priscilla L. Callison
Emmett Wright
Girish Govindarajan
Kansas State University
Manhattan, KS 66506

Don Powers
Western Illinois State
Macomb, IL 61455

Cindy Ford
Pittsburg State University
Pittsburg, KS 66762

The purposes of the study were to examine selected factors that related to concept map construction in three science topics: ecology, pendula, and astronomy. Thirty one preservice elementary teachers at a large midwestern university enrolled in an elementary science methods course during the summer of 1989 were the subjects. The researchers used the course's two laboratory sections as groups in which one group received hands-on instruction and the other group read about the three topics from text. The subjects were instructed in the construction of concept maps approximately four weeks prior to the beginning of the study. Subjects from both groups drew a concept map for use as a pretest before treatment and a concept map for use as a posttest immediately following treatment. Additionally, the subjects were asked to complete another set of pre-posttest concept maps which were used as a check for equivalence of groups since there was no treatment given. The concept maps were assessed for the number of correct relationships, hierarchies, branching of concepts, and links of branches one to another. This study is still in progress. However, cursory inspection of means and standard deviations from the number of relationship and map total scores suggests a trend that using a concept map as a dependent measure appears not to have much impact. Some of the possible questions to be addressed are:

1. What concerns about using concept maps as a dependent measure are revealed?
2. What is the score that represents the level of chance with a concept map?
3. What happened to the number of relationships over time?
4. Did the concepts listed on the concept map form act as a limiting factor to the number of relationships conceptually mapped?
5. Could lower scores on concept maps also indicate cognitive growth?
6. Are there limitations to the method of scoring the concept maps?

The results are discussed in terms of limitations of the present study as well as suggestions for future research.

IDENTIFICATION OF VARIABLES AFFECTING THE DEVELOPMENT OF SCIENTIFIC REASONING ABILITIES IN ELEMENTARY EDUCATION MAJORS

Carol L. Stuessy
Rebecca J. Pollard
Texas A&M University
College Station, TX 77843

Stuessy formulated and tested a model for the development of scientific reasoning abilities in adolescents. Piagetian theory provided the framework for choosing potential determinants of scientific reasoning. Causal relationships among the determinants and with scientific reasoning were hypothesized a priori on the basis of prior theoretical and empirical reports. Testing of the model by path analysis revealed significant path coefficients for these variables and scientific reasoning: age, IQ, field dependence-independence, and experience. A path from locus of control to scientific reasoning through field dependence-independence was also significant. The model was revised on the basis of these findings and explained 61 percent of the variance in the dependent variable.

The study currently in progress tests a number of paths found to be significant in Stuessy's revised model. An older group of students comprised the subjects for this study: elementary education majors (n = 60) enrolled in elementary science methods classes at a large southwestern university. Relationships are being tested between and among these variables and with the dependent variable, scientific reasoning: field dependence-independence, experience, and locus of control. Age and IQ were excluded from the study. These instruments were used in this study: Test of Logical Thinking (scientific reasoning), Concealed Figures Test (field dependence-independence), Rotter's Internal-External Scale (locus of control), and Cognitive and Recreational Activity Scale (experience). The statistical procedures of path analysis are being used to determine the strengths of the hypothesized relationships between and among these variables. Descriptive statistics and results of path analytic procedures will be reported.

Results of this research will lead to implications regarding the implementation and/or modification of particular educational strategies to improve the development of scientific reasoning abilities in elementary education majors. In an elementary education program that prepares elementary school teachers to teach scientific reasoning skills to their students, it is critical that elementary school teachers themselves possess these skills. Of particular interest is the role of experience in affecting scientific reasoning abilities. Experience is a variable that can be directly manipulated within the preservice elementary teacher's educational program to improve his/her scientific reasoning abilities. Activities previously suggested by a number of educators are promising as possible additions to an elementary science methods class. An experimental study determining the effects of adding science experiences such as these is planned for spring semester, 1990. Regarding the variables of locus of control and field dependence-independence, a number of researchers have

suggested that educational experiences should match the personological characteristics of these individuals in order to enhance academic achievement. Aptitude-treatment-interaction studies centered on matched and mismatched educational treatments are also planned to explore methods for enhancing the development of scientific reasoning abilities of elementary education majors.

A PRELIMINARY ANALYSIS OF PRESERVICE TEACHER PERCEPTIONS OF EFFECTIVE TEACHING

Cynthia T. Holland
Linda Cronin-Jones
University of Florida
Gainesville, FL 32611

The study was designed to (1) identify student teacher perceptions regarding the characteristics of an effective teacher, (2) to document the changes in these perceptions of effective teacher characteristics as students progressed through their internship experience, and (3) to identify major areas of focus in student teacher perceptions of effective teachers.

The seven pre-service teachers involved in the study were enrolled in a graduate level science teacher preparation program. All of the students had a bachelor's degree in their respective science subject areas. In addition, the students had all completed one semester of graduate coursework including science teaching methods, curriculum evaluation, and general teaching methods. Their ages ranged from 22-31 years. Two males and five females comprised the study group. The two researchers were university faculty assigned to monitor and assist the students during their internship.

The data collection process consisted of three stages and lasted four months. In the first stage, the students were asked to generate a profile consisting of no more than fifteen effective teacher characteristics. This list was generated one month before the internship experience began. The second stage of data collection commenced during the second week of the internship. Each intern was observed and interviewed every two weeks by alternate researchers. Each intern evaluated his/her self using his/her profile of an effective teacher. After each observation, the interns were allowed to add, delete, or change any item on their profiles. All interviews were audiotaped. The final stage of data collection consisted of a taped interview and a discussion of a final profile of an effective teacher developed two weeks after completion of the internship. During the interview the students were asked to reflect and comment on the changes that had occurred in their profiles as a result of the internship.

The systematic analysis of the effective teacher profiles was performed by the researchers in an attempt to identify patterns. As a result of the analysis, six main categories were identified. These categories were: learning environment, personal characteristics, management, instruction, planning, and assessment. Within each category statements were grouped

into teacher-focused or student-focused sub-categories. For example, the following statement from a profile: "Has a spontaneous sense of humor" would be classified as a teacher-focused personal characteristic. Another teacher-focused personal characteristic would be: "Has a solid content knowledge base." An example of a student-focused statement on assessment would be: "Assesses students in a variety of ways, allowing each student to demonstrate his/her strengths." Once these categories were identified, the taped interviews were then analyzed and lists of the main emphasis in each tape were generated. Similarities and differences between the tapes and student-developed profiles of effective teachers were examined.

Before completing internship experiences, the pre-service teachers in this study primarily focused on teacher-oriented personal characteristics and instructional techniques. As the internship experience progressed, these teachers reflected on their own performance and began to broaden their perspectives. As part of this process, their concerns shifted from being primarily teacher-oriented to being more student-oriented. In addition, as the internship experience progressed these pre-service teachers considered other aspects of teaching, such as the learning environment, assessment, planning and management.

These results indicate that the internship experience has a profound effect on pre-service teachers' perceptions of what behaviors and characteristics determine an "effective" teacher. These changes in perceptions are gradual and appear to result from direct experience and reflection.

These findings support current views regarding the role direct experience and reflection play in shaping individual perceptions.

AN ASSESSMENT OF PRESERVICE TEACHERS' KNOWLEDGE OF ENVIRONMENTAL PROBLEMS AND CONCERNS FOR ENVIRONMENTAL QUALITY IN BOTSWANA

Modise Mosothwane
Joseph P. Riley II
University of Georgia
Athens, GA 30602

As in many other developing countries, Botswana faces environmental problems associated with gains in technological and industrial developments. It has become increasingly apparent that the public must be made aware of environmental problems and their effect on the environment. Since teachers are delegated the responsibility of teaching environmental education in Botswana, there is hope that if teachers have environmental content knowledge, the right attitudes, and concern for environmental quality, they will be able to successfully implement environmental education program in their schools.

The purpose of this paper is to assess preservice teachers' environmental literacy. Preservice teachers at one of the two teacher preparatory institutions in Botswana were administered a series of tests to evaluate their environmental content knowledge, attitudes toward environmental education and its teaching, concern about environmental quality, and understanding of the goals of environmental education.

Initial results indicate that preservice teachers' concern about environmental quality is low. It can be concluded from the results that science educators in Botswana have a difficult task to fulfill, that of designing appropriate environmental education programs. Hopefully, if colleges of education in Botswana can develop strong environmental education programs, then preservice teachers will have the opportunity to increase their environmental literacy which will help them promote environmental awareness among the public.

LEARNING TO TEACH: CHOICES VS CONSTRAINTS

Zurida Ismail
University Sains Macaysia
D. Dinang, Macaysia 11800

Annette Larussa
University of Georgia
Athens, GA 30602

The primary purpose of this study was to determine how prospective teachers learn to teach and what kind of opportunity for learning student teaching offered to prospective teachers. The questions that were dealt with in this study involved looking at meanings and perspectives of the student teachers in relation to their practice within the context of a particular situation.

Four prospective secondary science teachers were observed and interviewed from the beginning of the methods course in fall, 1987 through the 10-week student teaching in spring, 1988. Interviews were also conducted with the cooperating teachers and university supervisors to examine the sources of influence related to the professional development and growth of the student teachers.

Field notes were taken during observations and interviews with participants were tape recorded and transcribed. Data were analyzed using methods of inspection and coding, constant comparison, analytic induction and description. Data were coded according to recurring themes. Case studies of each student teacher were then written, based on the assertions from the major themes. Lacey's conceptual model of choices vs constraints was used as a framework for the discussion of the participants' student teaching experiences.

The findings showed that student teachers still learn to teach by teaching and through trial and error, and that ecological classroom conditions act as constraints on their actions, and exert pressures to act in certain ways. Responses to the constraints not only depended on the student teachers' personalities, but also on their motivation and other demands that were placed on them.

The findings illustrated that each student teacher experienced his/her student teaching differently, depending on the relationships that were established with the cooperating teachers, pupils, and opportunities for learning to teach. Only one student teacher had the opportunity to fully

utilize the student teaching period to learn how to teach, with the support of the cooperating teacher. The other three student teachers were afforded varying degrees of freedom to explore and experiment and therefore were limited in the things they could do in class with the pupils. In addition, they were often frustrated in their attempts since they did not get support from either the cooperating teachers or the pupils.

The findings showed that older, more mature students were able to operate independently of their cooperating teachers. However, they would benefit more if there is mutual respect and support from their cooperating teachers. The ideal relationship for promoting professional growth and development seemed to be when the cooperating teacher and the student teacher treated each other as equals and partners in planning and teaching.

AN EXAMINATION OF ELEMENTARY SCIENCE METHODS TEXTBOOKS 1900-1989

Sandra K. Abell
Purdue University
West Lafayette, IN 47907

Although research has been done and standards developed concerning elementary science teacher preparation in the United States, little is known about the content of the elementary science methods course. The methods textbook provides a window into the content of such courses. In this study, thirty four elementary science methods textbooks, published in the United States between 1900 and 1989, are examined via qualitative content analysis. The analysis is aimed at discovering trends in topic coverage, emphasis, and content over time. Treatment of textbook topics such as the rationale for teaching science in the elementary school, teaching strategies, and learning theories are examined.

LEARNING PATTERNS OF COLLEGE STUDENTS USING AN INTELLIGENT COMPUTER ASSISTED INSTRUCTION TUTORIAL IN ENDOCRINOLOGY

Yehudit Judy Dori
Jerome M. Yochim
The University of Kansas
Lawrence, KS 66045

An intelligent computer assisted tutorial in endocrinology has been under development by the authors since March, 1989, at the University of Kansas as an enhancement to a basic undergraduate course in physiology. The main objective of the project has been to create a challenging learning environment for college undergraduate students. The program, which consists of about 160 "cards" (screens), has been incorporated into lectures in human physiology.

We have carried out a complete cycle of a pilot study on developing an ICAI tutorial for a college level science course. The study included developing the endocrinology courseware, implementing it in the "field" as an integral part of a regular human physiology course, gathering data about students' performance, analyzing it, and, consequently, inserting improvements in the tutorial. To analyze the way students use our program, we developed the Card Traversal Graph (CTG) tool. It has enabled us to visualize and distinguish four different learning patterns: (1) structured/systematic exploration - a thorough, logical walk through a sequences of cards; (2) book style exploration - copying or printing cards to be used later as a reference; (3) saw-tooth exploration - repeating the same series of consecutive cards several times in a row; and (4) foraging - looking around in an unstructured manner, visiting almost randomly cards from various stacks. These patterns were shown to be related to students' performance in the human physiology course.

The CTG is a powerful tool for two purposes. For ICAI tutorial developers it enables the detection of flaws and weak points along the learning paths. It also provides a means of assessing and improving the program under development, while still in the pilot study phase, and before it has been released for massive use. For science teachers, who may be expected to use such tutorials in increasing numbers, it helps define students' learning patterns, and, possibly, assists them in improving their learning strategies.

USING COMPUTER/LASER DISK INTERFACE TO TEACH EARTH SCIENCE/ASTRONOMY TO UNDERGRADUATE CLASSES

Pierce Farragher
University of Victoria
Victoria, B.C. V8W 2Y2

The demonstration will focus on the use of Computers and Laser Disks in an interactive mode. Several lessons have been prepared using Hypercard (Hypertext) and the applications of this technology in Science classrooms.

This technology allows the user to access information rapidly, to review frames or segments of movies efficiently and to use certain frames in a testing mode i.e., identification of rocks and minerals.

Also discussed will be the steps required by science teachers to write programs using Hypercard. Any teacher familiar with the operations of a micro-computer will be able to write and use such programs.

CONSTRUCTING MEANING IN LEARNING AND TEACHING SCIENCE WITH PROSPECTIVE TEACHERS

Pamela Engler
Jere R. Holman
Florida State University
Tallahassee, FL 32306

Years of research on effective teaching strategies, such as wait time, have failed to be translated into improved learning in the classroom. Knowledge of the strategies is insufficient without teachers' understanding constructed from experiences. There is a need to follow the process by which teachers learn what it means to teach science. Reflective writing in experience-based teacher education classes is analyzed in terms of the students' construction of what science is and how children learn. Implications for teacher education include the importance of the learning context and reflective practice.

Symposium

THE PROSPECTS FOR CHANGE IN MIDDLE SCHOOL SCIENCE EDUCATION

Janet Carlson Powell
Rodger W. Bybee
M. Jean Young
William C. Robertson
Biological Sciences Curriculum Study
Colorado Springs, CO 80903

During this symposium we will report the results of a year-long design study of middle school science education. This study is in progress now and focuses on three general questions. The three questions are:

1. What do we know about teachers that will encourage change in middle school science education?
2. What do we know about students that indicates the direction of change necessary for middle school science education?
3. What is implied about implementation that is necessary to sustain any recommended change?

In order to study instruction, curriculum, learners, and implementation on a national level we will review state guidelines, conduct case studies, survey and interview students, teachers, and administrators, review the literature, and commission papers from experts in the field. We will use this information to determine the status of science education at the middle level and determine what challenges must be met to change and improve that status.

QUALITATIVE STUDY OF SCIENCE IN NORWEGIAN ELEMENTARY SCHOOLS

Doris Jorde
University of Oslo
Oslo 3, Norway

The purpose of this research was to study the classroom climate, specifically focusing on the social interactions between teachers and students. The lessons were coded by observers and videotaped to give multiple sources of data. Conclusions from the classroom observations were that boys at each class level receive more attention than girls; a small number of students answer the questions in a class discussion; when given the choice, students prefer to work in single-sex groups; girls appear more bothered by a noisy, unstructured class than are boys; boys begin activities quicker than the girls; boys are more likely to make up additional experiments when they have finished assignments; and girls are more likely than boys to finish the written reports. The following teaching strategies were suggested: teachers should begin the class with an activity, rather than a discussion, to minimize the different science experiences that boys and girls bring to the class; group activities need to be designed to ensure that all students have an assigned task and have to participate in the activity; and the curriculum should focus on a variety of science topics rather than just in areas where one group of students are more proficient than others.

TEACHERS' IMPLEMENTATION OF A NATIONAL CURRICULUM: A CASE STUDY OF SCIENCE TEACHERS' OF COSTA RICA

Alejandro J. Gallard
San Jose State University
San Jose, CA 95112-9983

The purpose of this study was to determine educational policies and programs designed by the Ministerio de Educacion Publica (Ministry of Public Education) of Costa Rica influence secondary science teachers' attitudes about science teaching and learning. The method of investigation was interpretive. Eighteen secondary science teachers, Ministry - and other public officials were interviewed in the Spanish language. Teachers' lesson plans and examinations, public officials' and university publications were also collected. Analysis of interviews and the aforementioned documents indicate that educational policies and programs are designed to meet the needs of national governmental and private sector leaders. Their objective is economic development through a more scientifically and technologically literate population. A vehicle used by these leaders is the Contenidos Basicos de Ciencia.

The Contenidos Basicos de Ciencia is the K-12 national science program for the country of Costa Rica. The design of the educational infrastructure is such that all public and private school secondary science teachers must teach a certain amount of science phenomena every academic year. Specifically, secondary science teachers are obligated by educational policies to transmit to secondary students of Costa Rica, science phenomena considered to be necessary for economic development through the advancement of science and technology.

The national science program is designed to be taught to all secondary students. Therefore, regardless of socio-economic differences, or whether students live in a rural, inner city or urban environment, they all are supposed to receive the same treatment. Results indicate that urban students who attend private schools benefit the most from the national science program. These students are the most likely to pursue tertiary studies.

Secondary science teachers who participated in this study are aware of these differences. However, 16 of the 18 science teachers indicated they will not adapt the Contenidos Basicos de Ciencia to teach their students practical applications of science knowledge. These teachers were solely concerned with fulfilling the requirements mandated by the national science program for the science discipline they were teaching during a particular academic year.

The conclusions reached in this study indicate the design of the national science program is influenced by a wide-range of worldwide economic, political, sociological, and technological influences. In turn, the design of the national science program influences secondary science teachers' attitudes about the teaching of science. As a consequence, the manner in which science is taught places an emphasis on preparing youth for work and not the development of critical reasoning in science.

ATTITUDE AND ACHIEVEMENT OF STUDENTS IN AN ENVIRONMENT DOMINATED BY INDIGENOUS TECHNOLOGY TO THE USE OF THE COMPUTER FOR LEARNING BIOLOGICAL CONCEPTS

Olugbemiro Johnson Jegede
Ahmadu Bello University
Zaria, Nigeria

Peter Akinsola Okebukola'
Gabriel Ajewole
Lagos State University
Lagos, Nigeria

The use of computers to facilitate learning, a scheme that is in vogue in the developed world, is yet to make an appreciable inroad into the teaching-learning process in most developing countries. The cost of purchase and maintenance is the major inhibiting factor to the adoption of this high technology in the classrooms of these indigenous technology-dominated countries. Two specific questions were focused upon in the present study. These were:

1. What is the attitude of students who operate within an environment that predominates in indigenous technology to use of the computer in learning biological concepts?
2. Will students who live in an environment that is dominated by indigenous technology achieve better in biology when learning is undertaken with the use of the computer?

Achievement and affective data were collected from 64 students enrolled for a three-month Nigerian Joint Matriculation Examination in Biology. The subjects were divided into three groups. One group of 10 (6 boys, 4 girls) used the computer on an individual basis. Another group of 30 worked in 10 three-member cooperative learning teams. There was a girl in each team. The third group of 24 (15 boys, 9 girls) did not use the computer. They were taught the biological concepts by the second author. Group assignment was done on a random basis. When submitted to an ANOVA, the pretest scores generated an F-ratio of 0.69 ($p<.05$) for attitude and 1.03 ($p<.05$) for achievement leading to a verdict of group equivalence on the dependent measures. When compared on the attitude measure, the posttest means of the individual student group ($X=61.36$), the cooperative group ($X=79.41$) and the control ($X=20.23$) were significantly different ($p<.0001$).

On the achievement measure, however, the computer-assisted group was not better than the control, contrary to expectations, thus contradicting the findings of many studies carried out in a western setting. The F-test revealed no significant difference between the individual, cooperative, and control groups. The results further revealed that the girls in the cooperative group recorded significantly higher posttest achievement scores than those who worked alone. The girls in the computer-assisted group had a significantly more positive attitude towards the use of the computer as a learning tool in biology than did the boys.

Very firm conclusions cannot be drawn from the results of this study until studies in similar settings provide confirmatory data. The results are, however, indicative of the fact that the computer has the capability of exciting students in an indigenous technology-dominated environment. It may not bring about remarkable and significant gains in achievement when compared with the teaching methods in regular use in these settings. Perhaps when greater familiarity is established with computer usage the story may be different. Another set of studies in chemistry is currently underway to further test our hypotheses.

FOURTH, EIGHTH AND ELEVENTH GRADE STUDENTS' UNDERSTANDING OF POLLUTION

Michael J. Brody
University of Maine
Orono, ME 04469

This study assessed fourth, eighth and eleventh grade students' understanding of scientific, technological, and social knowledge related to pollution. A representative sample of public school students (n=105) in eleven Maine schools was selected and students were interviewed on four concept principles considered critical to a full understanding of the pollution problem. The concept of pollution is meant to include the much publicized issues of solid and toxic waste as well as air, soil, and water pollution. This study considers what a student knows as an "integrated set" or cluster of concepts related to pollution. This is a complex, integrated, and multidisciplinary conception of a natural phenomena.

Student knowledge was rated for each concept principle on a scale of: complete, high partial, low partial, or no understanding. Common misconceptions were also noted. Generalized correct concept statements of current student knowledge were identified.

The conclusions have implications for teaching about pollution and the design of science education curriculum materials based upon student knowledge. This information can help teachers better teach students about current, environmental problems and thus help learners gain an appreciation for the complex and multidisciplinary nature of science, technology and society and how they affect the environment.

THE EFFECTS OF STS ISSUE INVESTIGATION AND ACTION INSTRUCTION AND TRADITIONAL LIFE SCIENCE INSTRUCTION ON SEVENTH GRADE STUDENTS' CITIZENSHIP BEHAVIORS

Randall L. Wiesenmayer
Lock Haven University
Lock Haven, PA 17745

Peter A. Rubba
Penn State University
University Park, PA 16802

The purpose of this study was to determine the effects of employing an STS instructional model which addresses each of the four goal levels of STS education with seventh grade students, versus an instructional model containing only life science content, on the following variables: (a) participation in citizenship action on STS issues, (b) STS content achievement, and (c) life science content achievement. A modified version of the non-equivalent control group, quasi-experimental research design

was used with 17 intact seventh grade life science classes, ten of which received STS instruction (n=263) and seven of which received life science instruction (n=136). Twenty class periods of STS instruction were delivered by the students' regular science teacher beginning with Goal Level I and continuing sequentially through Goal Level IV. During the same 20 days, seven classes (control groups) received life science content instruction.

Data were collected on six dependent variables using two instruments. Four dependent variables reflected student participation in citizenship actions as measured in the Actions Taken on Public Issues (ATPI) test. The STS and life science content achievement were measured by the Questions About Science and Technology (QAST) test. Both tests were accepted as content valid by a panel of judges and the reliability of each instrument was established. A repeated measures ANOVA was employed to analyze the data collected.

From the QAST instrument, a repeated measures ANOVA revealed an interaction ($p < .01$) on the STS and life science content achievement subscales (pre- to posttest). The STS group scored significantly higher ($p < .01$) than the life science group on the STS content achievement subscale, but not on the life science content achievement subscale.

The researchers concluded that the employment of an STS issue investigation and action instructional model which addressed the four goal levels of STS education significantly increased seventh grade students' participation in citizenship actions on STS issues, and STS content achievement, but may have restricted their life science content achievement. Implications and recommendations are provided.

A STUDY OF THE QUALITIES TEACHERS RECOMMEND IN STS ISSUE INVESTIGATION AND ACTION INSTRUCTIONAL MATERIALS

Peter A. Rubba
Penn State University
University Park, PA 16802

Randall L. Wiesenmayer
Lock Haven University
Lock Haven, PA 17745

The purpose of the study was to secure input from potential users, middle/junior high school and high school science and social studies teachers, on the qualities they recommend be included in STS issue investigation and action instructional materials on pesticides and society. Teacher input was desired in seven areas: (1) Course Context -- science and social studies courses in which teachers would consider using pesticides and society instructional materials; (2) Concept Linkages -- science and social studies concepts that teachers believe could be taught within the context of pesticides and society instructional materials; (3) Length -- the maximum number of school days/class periods teachers could dedicate to pesticides and society instructional materials; (4)

Instructional Technology and Media -- the degree to which microcomputer technology and more traditional forms of media could be utilized in pesticides and society instructional materials; (5) Interdisciplinary Cooperation -- the degree to which science and social studies teachers could teach pesticides and society instructional materials in a coordinated manner; (6) Relevance -- factors that would make pesticides and society instructional materials relevant to the local community and its students; and (7) Teacher Background -- the teachers' perceived degree of preparation to teach pesticides and society instructional materials. The study was conducted prior to the development of STS issue investigation and action units on pesticides and society. The target population for the study included middle/junior high school and high school science and social studies teachers. The accessible population included the contact people for nine of the 1988 National Science Teachers Association (NSTA) Exemplary Programs, and colleagues of those individuals in science and social studies. Fifty-five members of the accessible population who volunteered were the sample. A questionnaire was developed for the purposes of the survey by the researchers, and its content validity established independently. It was distributed and returned by mail during April, 1989. Twenty-eight of the sample members returned the questionnaire by the end of April for a 51% return rate, a very acceptable return rate given that a large number of the 55 sample members may have unknowingly been volunteered to participate. Twenty-five of the questionnaires were analyzed. The respondents/teachers averaged 18 years of teaching experience with a range from 2 to 35 years. Most of the teachers held multiple teaching certificates and assignments (including science and social studies) across middle and/or senior high school grades. Data secured from the respondents on qualities they would recommend be included in STS issue investigation and action instructional materials on pesticides are summarized by the seven areas assessed, including the following two findings: (1) 76% of the respondents indicated that interdisciplinary cooperation was possible across science and social studies courses on pesticides and society instructional materials; and (2) 10 was the mean number of class period/days it was anticipated a cooperative effort could be sustained (SD = 8.9). A model for STS issue investigation and action units, particularly one on pesticides and society, for coordinated use in science and social studies is proposed, drawing upon the study's findings.

WHAT DO PROSPECTIVE SCIENCE TEACHERS UNDERSTAND ABOUT THE NATURE OF SCIENCE?

Michael J. Wavering
University of Arkansas
Fayetteville, AR 72701

In light of the controversies surrounding creationism and evolution, knowledge of the nature of science by preservice science teachers is important. In a summary of research about beliefs of teachers Grossman, Wilson and Shulman wrote, "that prospective teachers' beliefs about subject matter are as powerful and influential as their beliefs about teaching and learning." In the same review of research these authors comment on syntactic knowledge for teaching. Syntactic knowledge is the knowledge of the means by which new knowledge is brought into a discipline.

The question of this research was: what do preservice teachers know about the nature of science (syntactic knowledge); what are the religious beliefs that have implications for how they view science; and what effect does instruction on the nature of science have in changing their knowledge level?

The subjects of this study were secondary science methods students certified in the areas of science. Students were given a twenty-five question form on the first day of classes and on last day of classes for the semester. Questions were chosen from surveys by Roelfs and by Feder. Subjects could respond to the questions by selecting agree, disagree, or don't know. Between the first and second time students answered the questionnaire, they participated in science methods classes. Students read articles, were lectured, and held discussions pertaining to theories, laws, hypotheses, and scientific processes. Also, students discussed what these works said about the nature of science and how this affected the way they would teach a science class.

Twenty-two percent of the responses changed from the first testing to the second testing on the thirteen questions about the nature of science. Since the number scoring 7 or above changed by only one from the first to second test, changes in understanding were toward levels of uncertainty. More students were marking don't know instead of agree or disagree. Of the fourteen significant differences, six are for a change from agree or disagree to don't know. The change from agree to don't know on questions represent changes from an incorrect response to an uncertain state. The changes are, generally, in the direction of the correct answer or move from a certain incorrect response to don't know, which means that they are considering options to their previous response.

The number of hours of biology taken does have an effect on the changeability of responses. Students with more hours are less changeable in their responses. Religious orientation appears to have no effect on knowledge of the nature of science or on the changeability of this knowledge with instruction.

Instruction as to the nature of science does effect some change in knowledge about science. The importance addressing changes in syntactic knowledge is underlined by Grossman, Wilson, and Shulman, "We believe that they (preservice teachers) consequently run the risk of misrepresenting the subject matters they teach."

PRESERVICE PRECONCEPTIONS IN SCIENCE

Bruce Gurney
University of British Columbia
Vancouver, BC Canada V6T 1Z5

Constructivism is a view of learning that regards the learner as a sensemaker who actively (and often subconsciously) constructs meaning out of experience. Considering that ordinary experience is usually random and incomplete, personal understandings are often incompatible with conventional wisdom. As one consequence, these alternative conceptual frameworks have been shown to influence the meaning the student may ascribe to new information. Constructivist teaching strategies are those which regard seriously the prior ideas held by the learner, providing opportunity for students to articulate their personal conceptions, to negotiate the meanings they construct from their interactions with phenomena among both peers and instructor, and to encourage student reflections about new learning.

There are implications in a wide variety of instructional settings. One such setting is preservice teacher education. Hewson and Hewson remind us that student teachers are likely to hold alternate conceptions about the nature of their discipline, about the role of teachers, and--implicit in their view of the characteristics of good teaching--of the learning process.

This paper reports on the results of a collaborative action research project which was conducted at two university settings, the University of British Columbia and St. Francis Xavier University. Data in the form of anecdotal statements concerning student teacher conceptions of the nature of science, teaching and learning were gathered over two consecutive academic years. A questionnaire was administered to novice secondary science education students at the start of the program. In particular, one question which proved to be especially powerful in illuminating students' conceptions required students to construct a metaphor which reflected their personal sense about the teaching/learning process. The paper explores the effectiveness of the metaphor technique in addition to a discussion of the meanings implied in these metaphors. Additionally, ten of these same students were interviewed at three intervals over the course of the twelve month program at the University of British Columbia in order to expand on the ideas articulated in their original questionnaire and to follow the evolution of their conceptions over time.

An interpretive framework which was applied to the results indicated that student teachers' conceptions in these three domains lie along a continuum with ends characterized by "authoritative" (teacher-centered, science-as-knowledge) and "interpretive" (student-centered, science-as-inquiry) orientations to science and schooling.

These results have implications for preservice methods instruction and practicum coaching/supervision insofar as they point to the need to recognize the conditions and preconditions of the beginning teacher when devising strategies to enhance their personal understandings about the enterprises of science and pedagogy.

PERCEIVED SOURCES OF LEGITIMATION AMONG PRESERVICE SECONDARY SCIENCE TEACHERS

Annette LaRussa
University of Georgia
Athens, GA 30602

The purposes of this study are to discuss sources preservice teachers perceive as lending authenticity to their teaching actions and to themselves as teachers and to examine these perceived sources of legitimation in light of the roles the preservice teachers assumed in the preservice teacher culture. A concrete understanding of processes of legitimation for preservice teachers in light of the preservice teachers' assumed roles in the preservice teaching, and school cultures should be informative to teacher educators in planning meaningful preservice teacher education programs.

The study employed a qualitative research design. The study was conducted during the 1988-89 academic year. The sample for the study consisted of secondary preservice science teachers enrolled in science education at a major southeastern university. Data collection consisted of weekly or biweekly interviews with three preservice teachers who served as key informants; occasional interviews with other preservice teachers; observations in secondary science education foundations, methods, and curriculum classes; weekly, or biweekly observations of five student teachers spring quarter; and pre- and post-observational interviews with the student teachers. Data analysis was inductive and comparative. Open coding was conducted as described by Strauss. Following the identification of categories of interest, data analysis continued following a modified version of analytic induction. The findings reported in this paper reflect analysis around categories related to sources preservice teachers relied upon to establish the legitimacy of their teaching actions and to establish themselves as authentic teachers. Following the development of categories, sociological articles were reviewed to provide theoretical triangulation. The sociological concepts of legitimation and authentication were identified in this review and were used to further refine related categories.

The findings were descriptive in nature. The roles assumed by preservice teachers in the peer culture are described and the sources of legitimation appealed to by the preservice teachers during student teaching are presented. The findings suggest that the nature and philosophy of the preservice teacher education program, the nature of the peer culture, and the roles the preservice teachers assumed in the peer culture are likely to be reflected in the sources student teachers reply on for legitimation in student teaching. Those who are strongly authenticated in the peer culture are most likely to view themselves as the principle source of legitimation when they begin student teaching. Those who are authenticated by the teaching culture in their student teaching placements exhibit the most growth in their ability to articulate and implement their beliefs about teaching, while those who are not authenticated by the teaching culture must rely solely on themselves for legitimation. In the latter case, the preservice teacher is unlikely to exhibit much growth in his/her ability to articulate and implement his/her beliefs about teaching. As the preservice teacher is authenticated as a teacher, he/she is able to move from concerns about self to concerns about the students. It is no longer necessary for the preservice teacher to use student success as an indication of personal authenticity. Instead, the preservice teacher views him/herself as a teacher and is able to focus attention on the students' success rather than on establishing his/her own authenticity.

CHILDREN'S MENTAL MODELS OF GRAVITY AND THEIR PREDICTIONS OF THE VERTICAL MOTION OF OBJECTS

J. E. White
Shawn M. Glynn
University of Georgia
Athens, GA 30602

Conceptual change epistemologists contend that children's intuitive theories play a large role in learning new concepts. In fact, many researchers assert that what students learn depends on the conceptions they bring to the classroom. Thus, science learning and understanding can be facilitated by discovering children's existing knowledge and coordinating subsequent instruction with that existing knowledge. However, a significant problem at this time is that very little is known about children's scientific theories or conceptions prior to instruction and researchers are beginning to recognize the need to identify as well as characterize in greater detail these initial learning states. Thus, the present study is on the characterization of children's various knowledge states in science. These knowledge states will be called mental modes and the specific focus is on children's models of gravity and how these models influence children's interpretations and explanations of events.

While only preliminary data have been collected, the sample will include a total of 44 students selected from first, second, and third grades. Subjects were selected from a public school in a rural Georgia country. The school is located outside the core area of the county and serves lower class white (two-thirds) and black (one-third) families. Students were asked to make predictions about the motion of various pairs of objects which were dropped simultaneously. Following predictions, children observed the events and were asked to offer explanations of the results.

Preliminary data have been analyzed using the rule assessment approach and standard parmetric procedures. The rule assessment approach has the advantage of discerning the knowledge states of children rather than just comparing groups on the number of correct answers. Analyses reveal that different object dimensions (i.e., color, number, shape, size, weight) are more salient for different groups of children in making predictions about the motion of objects. In addition, it is becoming evident that children employ various mental models of gravity when making predictions about the motion of objects. For example, when size was deemed as the dominant dimension, subjects made different predictions about objects (i.e., larger objects fall faster) than when weight was deemed the dominant dimension (i.e., heavier objects fall faster). While only preliminary data have been analyzed, it is expected that the results of the study will reveal a within-concept developmental sequence, with children aged 5 to 6 years employing simplistic, single-rule mental models and thereafter increasingly adopting more sophisticated models.

A COMPARATIVE ANALYSIS OF BOYS' AND GIRLS' PERCEPTIONS OF SCIENTISTS BASED ON THEIR DRAWINGS

J. Nathan Swift
Donna Waick
Robert E. Schell
C. Thomas Gooding
Patricia R. Swift
State University of New York at Oswego
Oswego, NY 13126

The purpose of this research was to examine the pictorial representation of scientists as held by students and to determine if, after thought and the initial expressions of how scientists are viewed, students' perceptions expand or change. Students from all age groups were asked to draw a scientist. After this initial drawing, they were asked to draw more scientists on another paper. A total of 1240 drawings were examined. The following features were considered: (1) sex of the student, (2) age of the student, (3) sex of the student's science teacher, and (4) sex of the scientist drawn (neutral if gender was undistinguishable). Other variables the drawings portrayed were also examined, such as: (1) a lab coat, (2) eye glasses/goggles, (3) facial hair, (4) symbols of research (i.e., beaker, test tube), (5) symbols of knowledge (i.e., book, light bulb), (6) technology (i.e., computer, airplane), (7) relevant captions, (8) signs/labelings, (9) pencils/pens, and (10) unkempt appearance (i.e., messy hair, torn clothing). The average age of the students participating was 12.7, ranging from age 6 to 18. Descriptive analysis indicated 72% of the males drew male scientists and 28% drew neutral scientists. No males drew female scientists. Fifty-three percent of the females drew male scientists, 33% drew neutral scientists, and only 15% drew female scientists. Of the total number of scientists drawn, less than 8% were of females. The sex of the science teacher did not have a significant relation to the sex of the scientist drawn. No significant relationship was found among the variables. There was not a significant difference in what variables males and females drew. For the second set of scientists drawn, statistical analysis indicated that males and females drew about the same number of male scientists. Once again, females drew significantly more female scientists. It is important to note that males did include female scientists in their second drawings. There was also a tendency for males to draw more neutral scientists than females drew. As was found with the first scientist drawn, the sex of the teacher did not significantly influence the sex(es) of the second scientist(s) drawn.

AN INVESTIGATION OF THE DIFFERENCES IN ATTITUDE AND ACHIEVEMENTS BETWEEN MALE AND FEMALE SECOND AND FIFTH GRADE SCIENCE STUDENTS

Edward L. Shaw, Jr.
Robert L. Doan
University of South Alabama
Mobile, AL 36688

The purpose of this study was to investigate the difference in attitude toward achievement in science between boys and girls in grade two and in grade five. The need for such research is based upon the growing awareness among teachers, parents, administrators, researchers, and scholars that males outnumber females in science courses and science careers.

The subjects in the study were administered the Nybera and Clark Attitudinal Scale and the Stanford Achievement Test during the spring of the academic year 1984-85. The Nybera and Clark Attitudinal Scale was administered followed by the Stanford Achievement Test. Both tests were administered in the morning. The data collected were analyzed using independent t-tests. No a priori level of significance was established.

The results of this study indicate that the elementary students in grades 2 and 5 do not exhibit any gender differences in achievement and attitudes toward science. It appears that students in this study have not been negatively affected by their encounter with science instruction. The findings of Simpson and Oliver that apply to middle school students do not seem to apply to elementary students. Other research indicates that students in middle and high school receive less than adequate stimulation in their science classes to motivate them to pursue other science courses and a science profession. These studies seem to suggest, then, that the gender differences seem to commence at the middle school level and continue through high school and college.

The implications from this study indicate that early and continued valuable science experiences by students are necessary to avoid a negative attitude towards science in later years. This is not solely gender specific but appears to hold true for both sexes and grade levels; however, materials should be carefully selected to prevent girls from losing interest in science and science careers.

A LOGICO-STRUCTURAL, WORLDVIEW ANALYSIS OF THE INTERRELATIONSHIP BETWEEN SCIENCE INTEREST, GENDER, AND CONCEPT OF NATURE

William W. Cobern
Arizona State University - West Campus
Phoenix, AZ 85069-7100

Jane E. Ellington
Daniel M. Schores
Austin College
Sherman, TX 75091

To increase the involvement of women in science both as professionals and as enlightened citizens we must ask what it is that currently bars their involvement. We have a clue in the recent Belinky et al book Women's Ways of Knowing which suggests that there is a distinctly feminine world view. As other studies have indicated, worldview variations potentially interfere with science education, particularly when instruction proceeds unaware of the importance of fundamental epistemological structure in learning. The purpose of the research being reported here is to provide information about gender-related worldview structures among college students that can inform the instructional decision making process. This information is generated in a logico-structural investigation of the interrelationship of gender, interest in science, and concept of nature. The logico-structural approach to world view differs significantly from the monothematic approaches to world view based on Stephen Pepper's work, among others. The strength of logico-structuralism is its sensitivity to intra-worldview variation, and thus its avoidance of artificiality.

Worldview researchers primarily use a technique called "reading back." From observations one reads back to underlying presuppositions. In this study "concept of nature" was observed as college student responses to a direct question about nature. The preliminary results indicate that there are gender-related concepts of nature, indicating that women college students have presuppositions about nature that differ significantly from men. Secondly, the results suggest that among women college students concept of nature is related to interest in science but not related among men students.

MEASURING EQUITY IN THE SCIENCE CLASSROOM: A NEW TOOL

Lynnette Danzl-Tauer
Purdue University
West Lafayette, IN 47907

A number of studies in recent years document differences between males and females in science attitudes, participation, and achievement. Explanations for these differences include parent and teacher expectations and influence, gender role stereotypes, and perceptions of science and scientists. In the hope of getting more females involved in science, researchers have identified teaching strategies and classroom

characteristics that promote equitable classrooms. Kahle has shown that it is possible to teach or transfer equity-promoting skills to teachers that lack them. For such training to be useful, teachers who would benefit from equity training must be identified. This study involves the development of a tool, an "equity rating scale," which can aid researchers, administrators, and teachers in this task.

The "Science Classroom Sex Equity Rating Scale" is designed to measure teacher behaviors and classroom characteristics which have been found to encourage girls in high school biology classes to enroll in advanced science courses. Areas examined include: quantitative skill development, spatial skill development, career information, creation of cooperative and equitable classroom environments, and optimization of the physical classroom environment.

Work in progress includes the validation of scale items and the estimation of their reliability, as well as a comparison of teachers who score at the extremes of the scale.

THE DEVELOPMENT OF A GENDER ENVIRONMENT SCALE

Kathryn Scantlebury
Purdue University
West Lafayette, IN 47907

Teachers can perpetuate stereotypic cultural beliefs regarding girls' ability in, aptitude for, and suitability for science by their teaching practices and behaviors. As teachers have a major influence on girls' career choices, their equitable teaching practices in the classroom are important to help encourage all students, especially girls, to continue with science. Researchers have studied teachers with a history of retaining girls in science courses in order to search for common strategies and practices. They found that such teachers encouraged equal participation by girls and boys in class activities. They used text supplements highlighting contributions to science by women. Sexist humor was never used in their classes and instructional time was taken to discuss possible science careers. By eliminating the use of sexual innuendos and jokes in their classes, the teachers minimized the image of science as masculine. The inclusion of women in the discussion of possible career alternatives made girls aware that science was a viable career for them. These teaching practices and behaviors encouraged more girls to move into elective science courses such as chemistry and physics.

Although there have been several classroom environment scales to determine students' perception of their classroom environment, these scales were not gender specific, nor did they focus on the teacher behaviors that could promote an equitable classroom environment. The purpose of the Gender Environment Scale was to ascertain, in the opinion of the student, whether the teacher created an equitable classroom. The students were asked about

their perceptions of their classroom with respect to teacher questioning behaviors, disciplinary procedures, interactions with students and students interactions with each other. The foils in the scale were to focus on teaching practices and behaviors that had been shown by previous research to either contribute to or detract from an equitable environment.

The reliability of the scale was found to be 0.5862, and significant differences were found between boys' and girls' scores on the scale.

DIFFERENCES IN THE PERCEPTION OF THE SCIENCE CURRICULUM BY TEACHERS AND STUDENTS: AND THEIR IMPLICATIONS FOR THE DEVELOPMENT OF ATTITUDE

Michael D. Piburn
Arizona State University
Tempe, AZ 85287-1911

This is a part of a three-year project to develop an instrument to assess attitudes toward science that reflects scales generated by students rather than by researchers. It is based upon extensive interviews of the thirteen teachers of 150 students whose perceptions of the science curriculum was previously reported.

As was the case in the initial work with students, the method for this study was a semi-structured interview. The objective of this was to triangulate with student perceptions of the classroom experience.

Interviews of students and teachers have revealed a startling divergence of views about the science curriculum. This is especially disturbing because it will make initiation of the changes that are required to improve the attitudes of students doubly difficult. Teachers and others will have to come to see their classes through the eyes of students before major changes in the curriculum will be possible.

PERCEIVED ENCOURAGEMENT OR DISCOURAGEMENT IN THE USE OF HANDS-ON ACTIVITIES IN SCIENCE AND THE IMPACT ON TEACHING STYLES

Betty Crocker
University of North Texas
Denton, TX 76203-3857

Edward L. Shaw, Jr.
University of South Alabama
Mobile, AL 36688

Barbara Reed
Norcross High School
Duluth, GA 30136

Observations in schools by college supervisors indicate a gap between what a teacher knows on a theoretical level and what is actually done in classrooms on a practical level. For most teachers, the acquisition of a skill is not sufficient to produce a transfer of that skill into the classroom. Showers states "the conditions of the classroom are sufficiently different from the training situations that one cannot simply walk from the training setting into the classroom with the skill completely ready for use--it has to be changed to fit classroom conditions." How are teachers encouraged or discouraged from making this change so that transference can occur?

This study was to determine where teachers perceived encountering encouragement or discouragement for lessons involving hands-on activities in science, how strong this encouragement or discouragement was, and the effect this has had on their teaching style.

A questionnaire was developed and administered to 135 teachers. The teachers surveyed may be but are not necessarily teaching only science.

The "typical" teacher in this survey has been teaching grades K-3 for four years in a self-contained elementary school classroom, not teaching only science. She student taught in the same grade-level (K-4) and subject (all) range, and has either a B.S. or a B.A. Since she has had a science methods class since 1970, exposure to hands-on activities was probably part of the content emphasized in other methods classes.

Although discouragement was reported, it was always in smaller amounts than encouragement. Teaching experience, self, and cooperating teachers were sources that ranked within the top four important sources for both encouragement and discouragement.

The results indicate that a teacher's early experiences and his/her feelings of personal success have a direct impact on the continued or discontinued use of hands-on science activities in their classroom. The sources of the strongest encouragement to use hands-on experiences were Teaching Experience and Self.

Another source that appears to have a great deal of impact on teachers was their cooperating teacher during student teaching. Student teachers spend more clock hours with their cooperating teacher than with a science educator in a methods class. As a result, student teachers' philosophy and teaching style are influenced more strongly by their cooperating teacher.

Teachers indicated that they have received strong doses of encouragement, minimal amounts of discouragement, and that they have knowledge of a teaching style conducive to the successful use of hands-on teaching of science in their classroom. However, teachers indicated they are not teaching science in a style that is compatible with the strong hands-on emphasis received in their science methods class.

It appears, from the results of this survey, that there is not one particular source of active discouragement identified by these teachers. Two of the problem areas identified, teaching experience and self, are very difficult for science educators to address and therefore resolve. The results also indicated that these two identified areas also provide the greatest source of encouragement to use hands-on experiences in their classroom.

STUDENT RECALL AND ATTITUDE FROM READING TEXTBOOK PASSAGES ABOUT INSECTS THAT REFLECT DIFFERENT THEMES OF SCIENTIFIC LITERACY

David A. Fillman
Galena Park High School
Galena Park, TX 77547

Eugene L. Chiappetta
University of Houston
Houston, TX 77204-5872

The purpose of this study was to determine what students would know and how they would react to information on a biological topic when it was written to stress either science as knowledge, science as a way of thinking, or the interaction of science, technology, and society (STS). The written information in science textbooks is often used in science courses to present facts and concepts. The messages that these materials convey to students help to form their perceptions about the nature of science and its value to society.

Each of three reading passages were developed from a common list of facts about insects and entomologists. The factual information was written to emphasize one of three aspects of science education. A sample of 318 ninth-grade students, enrolled in a regular biology I class in a suburban school district in the Southwest, participated in the study. Biology teachers randomly distributed an equal number of each type of reading passage to each class of students. After reading a given passage about insects, the student completed an attitude instrument, followed by the completion of an instrument to measure recall of the science information.

The instrument to measure student interest in the narratives consisted of 12 items identical to or modified from items on the National Assessment of Educational Progress. Students circled their attitude towards a particular statement on a Likert-type scale ranging from strongly disagree to strongly agree. The instrument to measure recall of information consisted of multiple choice items from the fact list.

No significant differences were found among the three groups on attitude towards the textbook passages. There were also no significant differences on the text recall instrument between the mean scores obtained by students who read one of the three narratives. These data support the assertion that one or more of the narratives did not tap into a familiar schema already possessed by the students. They also support the contention that each narrative contained an approximately equal number and type of concepts. All familiar concepts were edited out of the three narratives. This finding has important implications for science textbook construction. For example, authors can probably construct textbook passages from any one of the three scientific literacy themes and produce similar student recall from text. Therefore, it might be appropriate to construct biology textbooks that stress more science as a way of thinking and STS. As long as the concepts that constitute what textbook consumers expect are included in these passages and those concepts are not subsumed to a lower propositional level, student recall of those concepts may not be affected.

This study supports the idea that equivalent content, written primarily from science as a body of knowledge, science as a way of thinking, or the interaction of science, technology, and society, seems to equally facilitate student recall from text. If the conclusion reached in this study is correct that students recall facts equally well, regardless of the theme of scientific literacy from which textual material is written, then the contention that increased STS in textbooks is a desirable goal may be achieved without sacrificing student recall from text. This need not be done by excluding important science concepts. As demonstrated from the construction of the narratives for this study, essential facts can be woven into the story.

GENETICS MISCONCEPTIONS IN HIGH SCHOOL BIOLOGY TEXTBOOKS

Nancy D. Green Glenn
Purdue University
West Lafayette, IN 47907

In 1983, Stewart showed through a series of problem solving sessions with students that even of students who could correctly solve monohybrid and dihybrid crosses, many did not have a conceptual understanding of how meiosis and genetics were related. Again in 1987, Stewart and Dale showed that the reason students could not solve "realistic" genetics problems was a lack of understanding of the mechanisms underlying transmission genetics. Although these authors give suggestions for teachers to help prevent misconceptions, there are other influences on the students' learning.

In 1984, Cho and Kahle demonstrated a direct linear relationship between the coverage of a concept in the text and student achievement. Thus, the high school biology textbooks cannot be ignored. After a review of the most frequently used high school biology textbooks, Cho, Nordland, and Kahle called for a change in the structure of how genetics and related topics are presented. They presented a list of suggestions to facilitate students' learning, and to help prevent the formation of misconceptions.

This research was conducted to see if there has been any subsequent change in the way genetics is presented in high school biology texts, and what amount of change takes place from one edition to the next.

Ten textbooks were evaluated, based on Cho et al's suggestions. First they were examined for the accuracy of the content in chapters or partial chapters covering meiosis, basic transmission genetics, advanced transmission genetics, human genetics, molecular genetics and applications in genetics (e.g., animal and plant breeding). They were also evaluated on consistency of symbols used from one topic to the next, A final criterion was the ease with which students could make associations between the processes of meiosis and Mendelian genetic principles. This was judged by the physical relationship of the topics in the text (number of sections separating) and whether any direct reference was made in the body of the text to the relationship. Where possible, the two most recent editions of texts were evaluated in order to understand whether the process of change is currently an ongoing one.

In the area of content, preliminary results show some major conceptual errors which are slowly being corrected. However, the consistency of symbols has not changed at all since Cho's recommendations, with different symbols being used for chromosomes both within chapters and between chapters. Another problem area is the representation of alleles. In the majority of textbooks, meiosis and transmission genetics were in separate chapters with only a brief reference to the relationship between the two concepts. Many of the newer textbooks (published in 1989) contained the same conceptual problems as their earlier editions, but tended to correct a percentage of the factual errors.

Symposium

SCIENCE TEACHERS' USE OF ANALOGIES: POTENTIAL AND PRACTICE

David F. Treagust
Curtin University of Technology
Perth, Western Australia 6001

Reinders Duit
University of Kiel
Kiel, West Germany

Paul Joslin
Drake University
Des Moines, IA 50311

Ivo Lindauer
University of Northern Colorado
Greeley, CO 80639

This symposium first presents a review of the literature regarding the role of analogies in science teaching and learning and provides discussion for the potential of analogy use in the science classroom. The second part of the symposium describes the practice of seven science teachers in the use and non-use of analogies as a part of their regular instruction.

Aspects discussed in the literature review include the different meaning of analogies, similes and metaphors in use in the literature; a philosophy and history of science view of the use of analogies (and their relatives); the role of analogies in the learning process; empirical research on analogy use; recommended approaches of analogy use in science teaching. The concluding view presented may briefly be summarised in the following statement: Analogies indeed may improve learning considerably if they are employed in an appropriate manner, i.e., if 'analogical reasoning' really happens. The constructivistic perspective underlying the review leads to the view that in every analogy there is a 'metaphorical aspect.' It is argued that this metaphorical aspect may enhance conceptual change learning because some anomaly and/or surprise is carried by it.

Research in the field of students' conceptions (alternative frameworks and the like) has provided much evidence that learning science is by far not as successful as is desirable. Strategies to facilitate conceptual change learning are needed in order to enhance learning. But the strategies available so far - despite some impressive progress - are still limited in really facilitating conceptual change learning. Analogies may facilitate conceptual change learning and are potentially valuable tools in science teaching.

The empirical research investigation was designed and executed to examine the frequency and manner in which seven science teachers in one school used analogies as part of their regular science instruction. Using ethnographic data collection procedures, the researchers collected data from 40 lessons of 70 minutes duration during four weeks of third term, 1988. Sources of

data primarily involved the researchers' field notes describing what happened in the classroom. Following the four weeks of observations in the classroom, intensive discussion about the use of analogies in science teaching were conducted with each science teacher.

Based on this research, the observations were interpreted under the following six assertions:

Assertion 1: Few analogies were used by the science teachers as part of their regular instruction.
Assertion 2: When the teachers employed analogies, they did so in a limited way.
Assertion 3: Exemplary use of analogies was infrequent.
Assertion 4: The teachers had an unclear understanding of an analogy.
Assertion 5: The teachers were aware of advantages and disadvantages of analogies.
Assertion 6: No teacher perceived a need for a repertoire of good analogies.

The results of the empirical study provide ambiguous data, not unlike the findings reported by other authors using intervention strategies for analogy use in teaching. The teachers in this study used few analogies in their teaching and tended not to use them in an elaborate manner even when such analogies were in the textbook used by the class. The teachers did not have a repertoire of good analogies to use in specific teaching situations, nor did they perceive the need for such a repertoire, and this may account for their lack of use. While the teachers tended to appreciate the beneficial and detrimental issues related to teaching and learning by analogies, they may have been unwilling to use analogies about which they were not confident of their success in helping students understand concepts.

The study in one school with seven science staff is recommended to be repeated elsewhere to ascertain whether or not the six assertions can be supported. Despite the potential contribution analogies can make to learning, given the potential for their misuse, more empirical data from the practices of classroom science teachers are needed to ascertain the type and frequency of analogies and the manner in which they are used as part of regular teaching routines. When analogies are used in daily teaching, how successful are they in eliciting student comprehension of concepts? The authors believe that the documentation of such naturalistic data can provide a necessary base for the design and use of intervention strategies and curriculum materials about analogy use in science teaching.

INTEGRATING COMPUTER INTERFACED VIDEODISC IN COLLEGE INTRODUCTORY BIOLOGY

Kathleen Ebert-Zawasky
Wheaton College
Norton, MA 02766

Gerald Abegg
Boston University
Boston, MA 02215

This study was designed as a systematic investigation of the feasibility and effectiveness of student authored videodisc presentations in a non-major introductory level college biology course. Students used a quick-learn authoring system, the Macintosh computer, and videodisc player with color monitor.

Sixty-six students were divided into three lab sections, two of which were designated experimental and one served as the control. No significant differences were found between the SAT scores for the lab groups. The experimental group formed working groups of three to view one demo lesson, develop one 15-minute presentation, and view eight peer-produced lessons. The control group viewed nine instructor-prepared videodisc lessons on the same topics. Students were tested for content acquisition and attitudinal changes.

Student authors were given complete freedom in deciding what videodisc material to include in their presentation. Despite this freedom, the mean scores on a criterion referenced test of students in the experimental group did not differ significantly from the control group. The experimental group exhibited a positive response to the assignment and suggested (nearly 2:1) that the assignment be included in future courses. Although working in groups, most students reported they assumed three roles (researcher, programmer, and presenter). Instructors and the student assistant all consider the method one that should be used again. Several independent variables (age, locus of control orientation, math SAT score, number of biology courses and computer experience) were tested for influence on the postest scores, and no significant effects were found.

VERBAL AND NONVERBAL BEHAVIORS OF "EXPERTS" DURING COMPUTER-BASED PROBLEM SOLVING IN GENETICS

Patricia E. Simmons
University of Georgia
Athens, GA 30602

Judith Kinnear
LaTroble University
Carlton, Victoria Australia

The study of genetics is an integral part of the curriculum in introductory biology courses at secondary and post-secondary levels. Results from previous genetics learning studies and needs assessments demonstrated the need for more intensive research in biology education in general and genetics learning and problem solving in particular. This study examined the verbal and nonverbal behaviors used by learners engaged in computer-based problem solving with a genetics computer simulation. The computer simulation, Kangasaurus, enabled the subjects to set up a particular genetic system (such as simple dominance or sex linkage) with which to demonstrate conceptual knowledge and to solve common prolems.

Ten subjects solved a series of conceptual understanding problems and exploratory genetics problems. Using a think aloud protocol in conjunction with videotape recordings, each subject's commentaries and interaction with the simulation were recorded.

The following stages of problem solving were extracted from verbal patterns of subjects and the computer monitor screen recordings: identifying the problem, representing the problem, reformulating the problem, planning the strategies, implementing the strategies, evaluating the strategies, and evaluating the solution in the context of the entire problem. The three subjects with an extensive knowledge of genetics reformulated the problem statement, selected specific strategies early in problem solving, focused on selective genetics principles pertinent to the reformulation of the problem, and employed the computer simulation to support their solution. Five subjects (not engaged in genetics research) also reformulated the problem statement, selected either specific or general strategies, explored various problem setups with the computer simulation before selecting one specific strategy, and generally employed the computer simulation as a medium through which they could solve the problem. Most subjects exhibited reflective problem solving behaviors (reflecting on the problem, the strategy, the solution, or the implementation of the strategy) concurrently with the other problem solving stages. Nonverbal behaviors were identified and coded from the videotaped recordings. Characteristic and repetitive behaviors (e.g. widening the eyes) accompanied various critical decision making points during problem solving.

The evidence from this study suggested that problem solving within the genetics domain is a complex process. Verbalizing during problem solving may have helped subjects in recognizing, analyzing, interpreting, and evaluating underlying patterns characteristic of specific inherited traits. The verbalizations were accompanied by predictable idiosyncratic nonverbal behaviors (e.g., furrowing eyebrows, tapping a pencil on the desk) which

preceded or paralleled critical decision points during problem solving (e.g., reformulating the problem) for the majority of subjects. Such behaviors may serve as cues which indicate various thought processes accompanying stages of problem solving. Current research on nonverbal behaviors and problem solving has focused only on counseling contexts of group problem solving, recognizing nonverbal signals in behavior-disordered children, or interpretations of teachers' nonverbal cues during questioning strategies. Examining and linking predictable nonverbal behaviors to critical decision points during problem solving may provide additional insight into problem solving processes.

This research study provided rich information about cognitive processes of learners engaged with genetics problem solving and instructional software. Additional naturalistic and experimental studies are needed to better understand learning and instruction in science and to develop learning models and appropriate instructional strategies.

COGNITIVE PROCESS ANALYSIS OF TEST QUESTIONS IN A COMPUTER-MANAGED COLLEGE BIOLOGY COURSE BASED ON A LEARNING STYLE ASSESSMENT

Claudia Melear
East Carolina University
Greenville, NC 27858

Claxton & Murrell wrote that, in higher education, an important question to be asked of any instructional strategy is whether that effort is consistent with the learning styles of the students concerned. Although there was a large amount of literature available on pre-college education regarding learning style, it was not until 1987 that support of this approach in higher education was evident through the work of Claxton & Murrell. Biologists designing courses for the non-biology major do not have data which quantitatively define them. The objective of this study was to provide those data, related to learning style and to learning environments, which could suggest changes to more appropriately provide for the non-major. A focus in the study was to identify if congruence exists between a measured amount of a cognitive process (analytic skill) and the resultant answer on a test question which required that skill.

Over 900 students enrolled at a large mid-western university in a non-majors biology course winter quarter, 1988, were administered the Learning Style Profile (LSP) produced by the National Association of Secondary School Principals (NASSP). The LSP contains 126 items divided into 23 subscales of research-based learning style elements which are classified into cognitive, affective, and physiological/environmental domains. Performance on one of the cognitive processes, analytic skill, was evaluated for 96 students. Included in the evaluation was (1) a determination of the amount of analytic skill required of six test questions in the computer test bank, (2) the students' score in the LSP analytic subscale, and (3) whether the students answered correctly or incorrectly. In an ANOVA, no significant differences were found of those students' analytical scores from the analytic subscale of the Learning Style Profile, based on any one of the three major variables (question level of difficulty, amount of analytic ability required as determined by ratings of three different persons, or right/wrong answer). A reanalysis of student answers based on a new analytic scale, composed of six items which loaded together in a 9-factor factor analysis solution, was performed and a significant three-way interaction was found between question type, amount of analysis and whether the student answered right or wrong ($p<.04$). These results suggest that there is a relationship between a measured amount of analytic skill (if a different and improved analytic subscale is used) and a student's ability to perform on questions which are perceived to require analytic skill. Biologists who design courses for the non-major may need to examine congruence between student analytic abilities and analytic requirements of instruction and test questions.

DESCRIBING CHANGES IN STUDENTS' COGNITIVE STRUCTURE BY USING AN INDIVIDUAL DIFFERENCE MODEL IN MULTIDIMENSIONAL SCALING

Wolff-Michael Roth
Appleby College
Oakville, Ontario, Canada L6K 3P1

The purpose of the present paper is to present a new qualitative and quantitative technique to describe changes in cognitive organization of science concepts. Individual difference models in multidimensional scaling and cognitive mapping were used jointly to describe temporal changes in students' conceptual framework and to describe changes in individual students' frameworks with respect to their peers and their instructor.

The results of two studies are reported. The subject for both investigations consisted of elementary education majors in their second or third year of studies at a large mid-western university. The students received science instruction as part of their course work. The science concepts were from the topical areas of phases/phase changes of matter and volume/surface area.

The data show that (1) students who receive instruction change their cognitive framework in the direction of that of the instructor; (2) students who do not receive instruction do not change in either amount of knowledge or in their content organization; (3) the relationships between concepts favored by the students are those that are show up most dominant in the instructors' data; and (4) instructors have significantly more and stronger associations between concepts than do the students even after a course on a specific topic.

Both studies attest to the power of the new technique, which makes concurrent use of the word association tasks, individual difference models in multidimensional scaling, and cognitive mapping. The paper discusses the advantages of the technique and its application to the study of longitudinal changes in cognitive structure.

AN INSTRUMENT TO MEASURE SPATIAL-SYMBOLIC INFORMATION PROCESSING ABILITY

Donna F. Berlin
The Ohio State University
Newark, OH 43055

Arthur L. White
The Ohio State University
Columbus, OH 43210

The ability to recognize, extend, and relate patterns and sequences to numeric, figural, and word representations plays a prominent role in science education. This study is part of an ongoing process to develop measures of spacial-symbolic information processing. The potential

contribution of this instrument to science education derives from three related factors: patterns, spatial ability, and analytic/sequential versus holistic/simultaneous processing. Science instruction at elementary and middle school levels should involve hands-on activities and the use of pictures, drawings, and diagrams. Instruction should focus upon relating patterns and sequences in the classroom to the real world environment. This type of instruction relies upon spatial aptitude and the ability to apply analytic/sequential and holistic/simultaneous processing skills.

A 57-item instrument, designed to measure spatial-symbolic information processing was developed. This instrument has resulted from a series of validation studies since 1985. The instrument was administered to a sample of 165 third, fourth, and fifth graders from a small-town/rural public school. There were 81 males and 84 females in the sample. The results of this data collection were subjected to principal components and factor analysis procedures to identify underlying constructs. Cronbach's Alpha internal consistency reliability estimates were computed for five scales determined from previous studies and for three scales resulting from this factor analysis. Grade Level by Gender multivariate analysis of variance was computed to determine relationships of spatial-symbolic information processing, as measured by this instrument, with Grade Level and Gender.

Three factors were identified by principal components analysis and clarified by a varimax rotation. These three factors accounted for 28.6% of the variance of the responses. Items with loadings of 0.40 or greater were grouped to comprise three new scales. These scales (factors) were identified as: Factor 1 - Numeric Patterns/Sequences (Alpha = 0.87), Factor 2 - Figural Patterns/Sequences (Alpha = 0.84), and Factor 3 - Word Concept Patterns/Sequences (Alpha = .95). The multivariate analyses of variance resulted in no significant Grade Level by Gender interactions and no Gender differences on any of the scales. Grade Level effects were found on four of the five original scales: Scale A (Figura Analogy), Scale B (Monotonic Progression), Scale D (Rule Application), and Scale E (Rule Identification & Application). Grade Level differences were also found for two of the three new scales: Factor 1 (Numeric Patterns/Sequences), and Factor 2 (Figural Patterns/Sequences). The upper grade level subjects scored higher than the lower grade level subjcts on the Numeric Patterns/Sequences scale. The Figural Patterns/Sequencing scale revealed differences between the third graders and both the fourth and fifth graders while the fourth and fifth graders were virtually identical.

These scales will help to obtain reliable measures of student abilities to recognize and extend patterns and sequences on tasks varying in representational forms (numeric, figural, and words) and representational levels (semiconcrete to abstract). This instrument will be valuable for detecting changes resulting from development of curriculum and learning activities designed to help students relate concrete and abstract understanding of concepts.

DEVELOPMENT OF A PAPER-AND-PENCIL INSTRUMENT TO ELICIT STUDENT CONCEPTS CONCERNING THE EARTH AS A PLANET

William E. Crews, Jr.
North Carolina State University
Raleigh, NC 27695-7801

This was a pilot study concerned with developing a paper-and-pencil instrument that could be used by classroom teachers to elicit and assess student concepts concerning the earth as a planet.

Previous studies in this area have used interviews to elicit childrens' ideas, but this technique is considered impractical for classroom teachers in middle school. Studies in other areas have developed two-tiered, multiple-choice tests, but this approach was considered too limiting in eliciting the wide variety of views known to be held by students. Therefore, the open-ended questions from the interviews were used as a possible compromise.

This study was divided into two parts. In the first part, the questions from the interview studies were administered via paper-and-pencil tasks to 76 middle school students in grades 6 and 8. In the second part, the earth-sun relationship questions were extracted, added to, and given to 178 seventh graders.

In part one, the performance of the students on the earth orientation tasks were compared to a regression line of the proportion of correct, earth-centered children combined from previous cross-age studies. The proportions of these sixth and eighth graders determined to be predominately earth-centered from the paper-and-pencil tasks were not significantly different from the proportions projected by the regression ($\alpha = .05$).

On the earth, sun, and moon relationship questions, the proportion of correct answers for the sixth graders on this instrument (76%) were similar to those from the interview study (73%) of Klein. Otherwise, there were no significant differences between the replies of the sixth and eighth graders using a Chi-square.

In part two of the study, the instrument developed containing the earth and sun relationship questions was able to show significant differences between ability-grouped classes, but the mean scores were not significantly different for classes at the same school that were not ability grouped. An internal reliability of .73 was determined using the Kuder-Richardson Reliability formula. In addition, a retest without instruction for 48 students after three weeks produced a correlation of .83 using Pearson's r.

Therefore, it would appear that the open-ended questions are a reliable way to elicit student ideas about this area of science.

PROFILING PRE-SERVICE ELEMENTARY TEACHERS' KNOWLEDGE OF DENSITY USING THREE ASSESSMENT TECHNIQUES

Marianne B. Barnes
University of North Florida
Jacksonville, FL 33216

Lehman W. Barnes
Florida State University
Tallahassee, FL 32316

Clive Andriesse
Edward White High School
Jacksonville, FL 32210

Current research supports the notion that science instruction revolves around experiential learning and integration of ideas on the part of the learner. These emphases are desirable at all educational levels and need to be initiated in the elementary school years. In order to plan and evaluate meaningful learning activities, elementary teachers themselves must posses a knowledge base and skills which emanate from their own positive experiences in science methods courses. These courses should be designed around the actual needs of future teachers, rather than driven solely by predetermined objectives and strategies. Research in the cognitive sciences, especially in the areas of conceptual scheme formation and approaches to problem solving which incorporate active searching for clues, has provided insight into learner needs. Determining their needs requires a variety of assessment techniques; meeting their needs involves applying current knowledge about the learning process to methodology courses.

This study involved 94 subject who were enrolled in elementary science methods courses at two universities in the southern United States. Their knowledge of density prior to instruction was assessed by three techniques: a two-tiered density inventory (reliability = 0.75) which provided true-false statements and a series of possible reasons for the statements, a problem-solving videotape which presents a problem situation (the "Golden Statuette") and requires that viewers actively search for clues, and a practical assessment of skills and concepts related to density. Demographic and attitudinal information was also gathered on the subjects.

The result is a profile of areas of strength and weakness of preservice elementary methods students which can be used to design appropriate instruction using their preinstructional declarative and procedural knowledge bases. The students w predominantly female and several indicated that they did not have good experiences in college science courses. The study of physics and chemistry generated most anxiety among the subjects. Tables were constructed to display umbers of correct responses and total response patterns on the Density Inventory. The average number of correct responses (each item included a true-false statement and a reason for response for a possible total of 20 points) was 10.6. In several cases a correct response was chosen with a wrong reason. Substantial numbers of students chose each erroneous reason presented in the items with a large number unable to differentiate mass and volume and density and volume.

After viewing the "Golden Statuette," most students reported observing a weighing procedure and a "putting in liquid" procedure. About one-third of the students said that, based on those two procedures, the storekeeper knew the statue was not gold; they did not elaborate on details of how the decision was made. Another one third actually was aware that mass and volume were being compared. Less than 10% included an appropriate density calculation in their responses.

The practical assessment caused most frustration and yielded information on both use of measuring instruments and individual problem solving strategies. Types of errors were recorded.

Clearly, looking at group patterns by means of paper and pencil assessments alone is not enough to ascertain methods students' cognitive patterns and needs. Practical assessment is "messy" business but gives a better account of individual differences. Multiphasic assessments can lead to better prescriptive teaching and modelling of strategies and tools which elementary teachers themselves can use with their students.

THE INFLUENCE OF PRESERVICE SECONDARY SCIENCE TEACHERS' BELIEFS ON PLANNING

Hsiao-lin Tuan
Annette LaRussa
University of Georgia
Athens, GA 30602

In the past decade, research in teacher education has shifted from an emphasis on teachers' behaviors to a focus on teachers' thinking. Researchers of teacher thinking identified topics such as teachers' beliefs and teachers' planning as areas of needed research. In order to design effective science teacher education programs, science educators must be aware of prior beliefs held by students, how these beliefs are likely to change during teacher education, and the sources which influence these beliefs. They also must know what preservice teachers value, how they perceive teacher education experiences, how they approach planning, and how their beliefs and expectations about teaching and learning compare to those of the teacher educators. The purposes of this paper are to describe categories of beliefs held by preservice secondary science teachers, to describe how the preservice teachers in our studies planned lessons, and to discuss the influence of their beliefs on their planning.

This paper draws on data from two studies of preservice teacher education. Both studies were conducted in the preservice secondary science education program at the same southeastern university. The informants for these studies were preservice teachers enrolled in secondary science education. Both studies employed qualitative research designs. Data collection consisted of semi-structured, open-ended interviews, observations, and lesson plans written by the informants. Both researchers also conducted classroom observations in the university methods classes and in the schools. Both data analyses were inductive and comparative. Initial categories were generated using the method of open coding. All available data were used to refine these categories.

The findings from both studies indicated that the preservice teachers shared many common beliefs, possibly reflecting the influence of the secondary science education classes. Most of the preservice teachers placed importance on science process skills and valued understanding science concepts over memorizing scientific facts. They believed students should be actively involved in learning science and that science teaching should employ concrete activities which allow students to be actively involved in constructing scientific knowledge. Most of the informants have similar concerns about organization and timing in planning their lessons.

The findings from these studies support the contention that beliefs are a dominant factor in influencing teachers' planning. The beliefs expressed by the preservice teachers in our studies reflected influences both from their previous school experiences and from their science education courses. Contrary to the opinions of many researchers these findings indicate that teacher educators may influence previous teachers' developing beliefs, or reinforce existing beliefs. Since the ability to clearly articulate their beliefs strongly impacts preservice teachers' ability to plan and evaluate their effectiveness of their planning, we recommend that science educators promote self-reflection among preservice science teachers.

VIDEOTAPE ANALYSIS OF THE RELATIONSHIP BETWEEN TEACHERS' HANDS-ON TEACHING EFFECTIVENESS AND STUDENTS' GAINS IN SCIENCE ACHIEVEMENT

Robert L. Hartshorn
J. Preston Prather
Ramona Nelson
The University of Tennessee at Martin
Martin, TN 38238

"Hands-on-science" teaching methods rank among the top research interests of elementary science teachers. This report describes a teacher-enhancement program designed to provide instruction for 16 elementary teachers on the use of concrete manipulatives in classroom science teaching. It details development and administration of an instrument to measure the extent to which the teachers made a transition toward the use of that mode of instruction in their classrooms, and it correlated their hands-on teaching effectiveness with their students' gains on an achievement instrument. For this study, each teacher was required to teach four science lessons on selected lesson topics to his/her elementary class at assigned times over an 18-month period. The teachers were required to videotape each lesson, using portable videotaping equipment supplied for that purpose by the Institute. The lesson assignments were scheduled to provide a basis for comparison of the extent to which each of the teachers used "hands-on-science" teaching techniques prior to, during, and after being instructed on their use. A total of 64 lessons (four each for 16 teachers) was videotaped and submitted to the project faculty for review. This study required the development of criteria for the quantitative and qualitative assessment of the teachers' use of concrete manipulatives and the nature and extent of student involvement. The resultant evaluation instrument was designed for use by a jury of reviewers, who would examine patterns of teacher behavior and pupil involvement from the videotaped lessons. A jury of three evaluators with strong backgrounds in teacher evaluation and "hands-on-science" instruction was selected to view the taped lessons and compare teacher performance. Pre and post administration of an achievement instrument served as the means of assigning each student's level of achievement. The results of the study indicated substantial transitions from the use of traditional student-passive teaching techniques to student-active methods. Preliminary analysis of the teachers' hand-on effectiveness and their students achievement spurred further investigation into the relationship of these variables.

USING INTERNSHIP-GENERATED STS CURRICULUM PROJECTS AS A FOCUS FOR FACILITATING TEACHER ENHANCEMENT

Carole P. Mitchener
Paul S. Markovits
Jerilynn Changar
University of Missouri - St. Louis
St. Louis, MO 63121

The context of the study is an on-going project in which teachers are asked to develop an STS curriculum project based on the knowledge they gain from a summer internship experience. The development and implementation of this curriculum served as the focal point for engaging teachers in reflection of their instructional practice.

This is a qualitative study which spans a three-year period. The study is currently in progress. The purpose of the study is to develop a teacher enhancement model which does four things: (1) engage teachers in the act of reflection on their instructional practice; (2) broaden teachers' societal perspectives of technology and how it interrelates with the sciences; (3) develop teachers' abilities to integrate new knowledge in technology as well as curriculum foundations into their science or math curriculum; and (4) enhance teachers' professionalism through experience into meaningful curriculum.

The methods of data collection include clinical interviews, written responses, tape recorded deliberations, on-site visits and informal discussions. The participants are 14 secondary teachers of science and math.

Although the study is still in progress, preliminary data show that teachers unanimously viewed the internship portion of the project as successful and pleasurable. The teachers described the internship experience as an exciting and motivating force which caused them to look forward to returning to the classroom.

The curriculum component was viewed differently. Translating internship experiences into curriculum materials was stressful and difficult for the teachers. However, the teachers later stated that it was the curriculum work that was the key to making the experience valuable in a broader sense, and that the curriculum workshops and seminars were extremely important elements to this process.

Data are currently being collected on how all of this translates into the classroom.

THE EVALUATION OF A K-6 SCIENCE INSERVICE PROGRAM: EXAMINING AN EFFECTIVE DELIVERY MECHANISM

Charles R. Barman
Jill D. Shedd
Indiana University
Indianapolis, IN 46202-5155

The purpose of this project was to evaluate a K-6 science inservice program. This program was conducted in six three-hour workshop sessions and consisted of hands-on activities, problem-solving exercises, and large and small group discussions. The individual workshop sessions focused on incorporating the science process skills in elementary science lessons, the use of effective questioning techniques, and the use of the learning cycle approach in teaching science.

Eighteen elementary school teachers from a midwestern school district participated in this project. Qualitative and quantitative procedures were used to evaluate the extent to which these teachers incorporated the information presented in this inservice program into their science teaching.

Before the inservice started, the participants were interviewed to gain baseline information about their attitude toward teaching science. Following the interviews, each participant was given a science topic for which they were to outline a lesson plan. A quantitative analysis of these lessons was conducted to determine to what extent they followed the learning cycle format. In addition, eight of the participants were randomly selected and observations were made of their science teaching.

The participants were asked to develop two additional lesson plans, one at the midpoint of the program and another once the program had ended. At the conclusion of the program, each participant was interviewed and classroom observations were conducted in the classrooms of the same set of participants as observed earlier.

The results of the evaluation suggest that the participants' attendance in the inservice program did impact their science teaching. Several participants indicated that they had gained a "philosophy of teaching" from this program. The pre- and post-classroom observations indicated that the participants used the learning cycle approach more after the inservice than they did at the beginning. In addition, a quantitative analysis of the lessons prepared at the beginning, midway through the inservice, and at the end of the program showed a significant difference in terms of their reflection of the learning cycle format.

RESULTS OF AN INSERVICE WORKSHOP TO PROMOTE SCIENCE-TECHNOLOGY-SOCIETY INSTRUCTIONAL ORIENTATIONS

Lawrence C. Sharmann
Kansas State University
Manhattan, KS 66506

The primary intent of this study was to examine the influence of a one-week intensive inservice workshop toward the recognition of more contemporary goals of science education and for developing science-technology-society instructional themes. In addition, it provided for a promotion of the "Learning Cycle" as an alternative instructional strategy and an examination of teaching techniques involving visual technologies. Finally, the workshop provided an opportunity for participants to identify environmental issues of local importance; issues that could be used as vehicles for developing interdisciplinary instructional cooperation among science and social studies teachers. Inservice participants consisted of a group of 13 certified, experienced teachers (5 or more years of employment) from rural school districts whose instructional assignments were either primarily science or social studies with a requirement to also teach science.

Data were collected both prior to the first day's and immediately following the last day's workshop presentations and activities. To assess inservice participants' initial and final orientations toward more contemporary goals of science education, an 8-item, bi-polar instrument entitled the "Contemporary Goals Survey" (CGS) was administered. In addition, to assess participants' understanding of and concern for the use of Science-Technology-Society (S-T-S) instructional themes, the well known "Stages of Concern" (SoC) instrument was administered simultaneously with the CGS.

The CGS data analysis, using the nonparametric Wilcoxon test, indicated significant differences between Pretest and Posttest scores for seven of the eight item statements. Each of these differences were in a direction consistent with a contemporary goals orientation as defined by the National Science Teachers Association in a position paper regarding S-T-S instruction. The overall score difference on the CGS instrument was also highly significant ($p < 0.001$). To provide further evidence regarding the potential effectiveness of the inservice workshop, the CGS was administered to a group of sixteen science and social studies graduate students enrolled in a Master's/Doctoral level course entitled "The Science Curriculum." Although graduate students' overall scores were slightly higher than their inservice counterparts, no significant differences between graduate and inservice "pretest" orientations were found. However, graduate students' overall scores were still significantly lower than inservice "posttest" results ($p < 0.001$).

Finally, a qualitative examination of SoC profiles among inservice "pretest" and inservice "posttest" data indicated a shift away from the three lower (Awareness, Informational, and Personal) and toward the three higher (Consequence, Collaboration, and Refocusing) Stages of Concern toward S-T-S instruction. Consistent with the CGS data, the graduate students' SoC profile fell directly between the two samples collected from the inservice teachers and more similar to the profile of the "pretest" inservice results.

The results of this study indicate that an intensive inservice workshop is capable of promoting a significant shift in instructional orientation in a direction consistent with the stated goals of the National Science Teachers Association. Such a conclusion is in concert with the views of McIntosh and Zeidler when they suggested the need for a more direct effort to disseminate NSTA, NARST, and AETS goals at the local level.

SELF-PERCEPTIONS AND PROFESSIONAL DEVELOPMENT IN ELEMENTARY SCHOOL SCIENCE TEACHING

David L. Haury
Tufts University
Medford, MA 02155

As the science education community moves toward development of national guidelines for science programs, it is important to keep in mind that professional growth of teachers remains central to the school improvement process. The amount of science taught is largely determined by teacher beliefs, knowledge, and actions. Unfortunately, elementary school teachers perceive themselves inadequately prepared to teach science, are reluctant to teach science, devote little time to science in the curriculum, and express resignation to situational barriers that inhibit science teaching. A significant number of elementary teachers do not perceive themselves to be efficacious as science teachers.

A variety of approaches have been used to study self-perceptions regarding personal efficacy. These include such constructs as locus of control, attribution theory, self-efficacy, and learned helplessness. Self-referent cognitions regarding control and personal efficacy seem to greatly influence what one chooses to do or avoids doing in a given context. In the context of elementary school science teaching, it seems desirable to find out what self-perceptions teachers hold, what factors influence the development of self-perceptions, how the self-perceptions influence classroom behavior, and how to foster self-perceptions which lead to appropriate science teaching.

Using an area-specific scale to measure locus of control in science (SciLOC), it has been shown that preservice elementary teacher's self-perceptions regarding control can be measured and modified in a desired direction through instructional experiences. It has also been shown that science locus of control orientation is related to attitudes toward science teaching and anxiety toward science teaching.

This study was designed to determine whether these relationships hold with experienced teachers. If so, they may have implications for designing professional development activities. Exploratory studies with practicing teachers included testing an abbreviated scale intended to measure locus of control in science, correlating control orientation with attitudes toward science teaching, and comparing scale results to perceived inservice needs in science.

Subjects included 23 elementary school teachers from three urban districts. At the conclusion of a two-week-long science institute, subjects responded to combined attitude and control scales, and they responded to questions about their needs in preparing to teach science.

Control orientation was reliably measured (Alpha > .70), but there was limited range of variance in attitudes and control orientation. Therefore, some results are rendered inconclusive. The relationships between control orientation and attitudes toward using textbooks, teacher involvement in curriculum development, and desire to work with various resource people are discussed.

These preliminary results seem to indicate that control orientation may be a viable construct to use in examining and improving teacher inservice workshops or professional day activities in science.

A RETROSPECTIVE EVALUATION OF THE PROGRAM TO IMPROVE ELEMENTARY SCIENCE

Edward J. Zielinski
Bruce G. Smith
Clarion University of Pennsylvania
Clarion, PA 16214

The purpose of this study was four-fold; to determine whether or not the participants in the PIES courses demonstrated significant gains in knowledge and attitudes as a result of the courses, did these hypothesized knowledge changes persist over time, and was there an associated increase in the participants' proclivity to do science which was also stable over time?

Since the beginning of the PIES courses in 1983/84, each time a course was taught, the participants were pre- and post-tested. These data were used in the first portion of the study. In addition, randomly selected participants from each of the sites and years, along with two different control groups, were administered two additional evaluation instruments in the fall of 1988. The returns from this survey were the data used in the longitudinal portion of the study.

The subjects of the investigation consisted of three types. The experimental groups were elementary teachers who had participated in a PIES course sometime within the last six years grouped by two-year increments. The average control group consisted of elementary teachers who had the responsibility of teaching science but had not taken a PIES course. The second control group consisted of a highly-motivated group made up of elementary teachers who belonged to the state Science Teachers Association but who had not participated in PIES.

Four instruments were used in this study. The PIES test was a 50 item, multiple choice instrument measuring knowledge and comprehension of basic science content and process. The second instrument used was the Science Attitude Scale for Inservice Elementary Teachers, a 26 item instrument to assess teacher attitude towards the teaching of science. Third was the

Science Proclivity Test, a 25 item instrument to measure the inclination or disposition of elementary teachers to do activity-oriented science lessons. Finally, the PIES Evaluation Project Knowledge Test was a 25 item, multiple choice instrument sampled from the original PIES test.

The results from the extant data indicated a significant difference occurred every year the PIES courses were conducted. Also, the analysis of the extant data indicated that a significant difference on the attitude variable occurred for every year the PIES course was conducted. No significant differences were found when comparing the mean scores for the groups who had taken a PIES course and the highly-motivated control group. Significant differences were found when comparing each PIES group to the average control group in the area of knowledge of science and science processes. No significant differences were found when the mean scores for the PIES groups were compared to the highly-motivated control group on the proclivity to do science variable. Significant differences were found for every PIES group as compared to the average control group on the proclivity to do science variable. Analysis of variance did not indicate any significant differences between the PIES groups on the knowledge variable regardless of when they took the course. Analysis of variance did not indicate any significant differences between the PIES groups on the proclivity to do science variable regardless of when they took the course.

When knowledge and proclivity variables were compared with the average control group up to five years after taking the course, a significant difference was found in every instance. The failure to find significant differences between any of the PIES groups implies that the knowledge gained and proclivity to do science obtained is stable for at least five years. The needs assessment portion of the study indicates elementary teachers need more materials and equipment to teach science effectively, and physical science is still the area of science they are most uncomfortable teaching.

THE COMPUTER PARTNERSHIP: A CASE STUDY OF THE DEVELOPMENT OF A SCHOOL/BUSINESS PARTNERSHIP

Karen K. Lind
University of Louisville
Louisvill, KY 40292

The Computer Partnership consisted of a working relationship between a financial institution, a community group, a large urban school district, and a university. These groups were joined together to partner the implementation of computers into two socioeconomically divergent middle schools over a three-year period.

The purpose of this study was to examine the dynamics occurring in the initial stages of this educational partnership formation. In this study, the nature of the partnership was explored; that is, how the partnership was initiated, how decisions were made, who made the decisions, and how power, authority, and communication were utilized.

A qualitative research approach utilizing firsthand data gathering techniques of observation, interview, and document review. A data analysis model consisting of data display, and conclusion drawing/verification was used as a way to discerning what was happening in the evolving partnership.

The findings and conclusions drawn from this case study illustrate that educational innovations are not separate from the organizational structure that surrounds them. If education and business are to effectively work together in implementing computer education and in providing quality instruction, they will need to carefully consider the organizational setting of the school districts in which they implement their partnership. This study suggests several pitfalls that might hamper computer implementation and offers recommendations and strategies for policymakers to consider when planning and implementing educational partnerships.

ASSESSING STUDENTS' CONCEPTIONS IN BIOLOGY USING PREDICTION PROBLEMS

Derrick R. Lavoie
Wayne State University
Detroit, MI 48202

Prediction is a science process skill that is fundamental to the progress and value of science. It has been recognized as an essential component of scientific inquiry and a terminal objective for science education curriculum development.

Prediction appears to be an extremely useful tool for facilitating conceptual change. Making predictions reveals students' prior knowledge and establishes personally committed conceptions to be compared with alternative scientific conceptions.

Before "prediction power" can be fully applied in the science classroom, research is needed to elucidate its "mechanism." This mechanism is dependent upon the relationship between procedural (skill/process) and declarative knowledge (factual/propositional), which is currently an important area for cognitive science research. Difficulties in studying prediction arise, since different methodologies assess procedural or declarative knowledge to various degrees.

Two methods that can assess both procedural and declarative knowledge are "prediction problem sheets" and "think-aloud interviews." Prediction sheets require students to make a predictions and justify them in writing. Think-aloud interviews present prediction problems to students and require them to think out loud as they attempt to solve them.

The objectives of this research "in progress" are to: (1) compare prediction sheets with think-aloud interviews for their capabilities of identifying students' conceptions and cognitive processes involved with solving prediction problems, and (2) examine the relationship between students' procedural and declarative knowledge.

Five pre-service students from a secondary methods class (science majors) and five from an elementary methods class (non-science majors) will solve the prediction problems during videotaped think-aloud interviews. Prediction problem sheets will be administered to pre-service students enrolled in a secondary science methods course (science majors) and those enrolled in an elementary science methods course (non-science majors).

Fifteen prediction problems in biology will be developed which describe a problematic situation involving several variables under selected conditions. Students will be required to predict the effect on the system when one particular variable is changed. They will then be required to give an explanation for their prediction.

Students' procedural and declarative knowledge conceptions will be qualitatively compared relative to conceptual accuracy, predictive success, and procedural models. This will involve techniques of verbal protocol analysis and a conceptual understanding scale. Information processing theory, which has proven quite useful for studying how people think, provides the theoretical framework.

The findings should help science teachers to: (a) develop more effective prediction problems in given subject matter domains, (b) maximize conceptual learning using the procedural and/or declarative knowledge information obtained with prediction sheets and think-aloud interviews, (c) motivate students to engage in stimulating discussions following predictions and conduct further experiments to test their predictions, and (d) develop teaching strategies for enhancing students' prediction skills and for promoting conceptual change. Guidelines will be developed for the integration and application of prediction problems within the traditional science teaching classroom.

AN EVALUATION OF THE SMALL INSTRUCTIONAL GROUP IN THE SECONDARY BIOLOGY CLASSROOM

Steven R. Rogg
Miami University
Oxford, OH 45056

The analysis of interaction within small instructional groups has been a useful technique for the understanding of group processes. It is understood that classroom, group, and student characteristics modulate interaction within a group which in turn can predict student academic, social, and socioemotional gains. Student on-task engagement, level of cognition, helping behavior, and group cooperation are readily characterized by studying interaction. It follows then, that many of the pending questions about small instructional groups in the secondary biology classroom might lend themselves to interaction analysis.

This research was designed to study the following questions: (1) Do contemporary understandings of small group instruction, which are mostly set in the elementary and/or non-biology classroom, apply to the secondary biology classroom as well? (2) Is the group interaction distribution pattern a useful predictor of student academic gain? (3) Are cognitive-

level descriptions of interaction useful for predicting academic gain? (4) How are student and group characteristics related to the frequency, type, quality, and distribution of interaction within the small instructional group?

Observations were recorded from small instructional groups (n=46) of three to five students in two ninth-grade academic biology classrooms. Data were collected by two trained observers over two three-week (teacher designed) instructional units. Observers utilized a diagrammatic recording instrument to mark interactions according to sender/receiver, on/off task behavior, "knowledge level" or "higher" cognitive level, and helping behavior (statement/explanation). Noncategorical general observations were also recorded. Distribution patterns of group interaction were derived from these data and indices of centrality were calculated which are hypothesized to reflect group cohesion or viscidity.

Student demographic information, general ability, locus of control, achievement, and personality (type preference) data were also collected. Analyses of these data included comparisons of each criterion variable with student and group interaction data. Of interest is the extent to which student interaction, group interaction distribution, and interaction type predict academic achievement.

THE EFFECTS OF HANDS-ON, MINDS-ON TEACHING EXPERIENCES ON ATTITUDES OF PRE-SERVICE ELEMENTARY TEACHERS

Jon E. Pedersen
Donald McCurdy
University of Nebraska
Lincoln, NE 68588-0355

The University of Nebraska-Lincoln offers a unique and creative approach to teaching elementary science methods. The science methods class consists of one hour of lecture and two hours of laboratory three times per week. Since the backgrounds of the students are very weak in science, the lectures deal with science content as well as methodology. The laboratories are arranged so that there are approximately 24 students in each lab. The labs deal with such practical topics as maintaining an aquarium and terrarium, utilizing community resources, exposure and certification in Project Wild (an excellent outdoor education program sponsored by the Western Association of Fish and Wildlife Agencies and the Western Regional Environmental Education Council). The major emphasis of the lab, however, is three peer teaching experiences in which the students teach each other lessons drawn from current curriculum materials and from the successful elementary science programs of the 1960's and 1970's.

The current study examines how the science methods program affects pre-service elementary teachers' attitudes toward teaching science. A pre-test/post-test design was used in evaluating the change in attitude over the course of the semester. Results of the study indicate that the methods course positively influenced attitudes toward teaching science for all students. A secondary concern of the study involved the correlation of the pre-service elementary teachers' attitude towards teaching science. A moderate positive correlation between the two dependent variables was found.

Symposium

THE NATURE OF "EXEMPLARY" SCIENCE TEACHERS: IMPLICATIONS FOR TEACHER EDUCATION

Robert E. Yager
The University of Iowa
Iowa City, IA 52242

Barry Fraser
David Treagust
University of Technology
Perth, 6001, Western Australia

Avi Hofstein
The Weizmann Institute of Science
Rehovot, 76100, Israel

Ronald J. Bonnstetter
University of Nebraska
Lincoln, NE 68588

Kenneth Tobin
James J. Gallagher
Michigan State University
East Lansing, MI 48824

In order to provide a refreshing alternative to the majority of research reports which malign science education and highlight its major problems and shortcomings, a series of case studies of exemplary practice in science teaching was initiated in three nations to provide a focus on the successful and positive facets of schooling. It was assumed that much could be learned from case studies of exemplary practice that would stimulate and guide improvements in science education, especially with such an international perspective.

In contrast to the research which casts a gloomy picture over schooling, especially science education, there have been some more optimistic research endeavors in recent times which highlight educational accomplishments and pave the way for improvements in schooling. For example, the effective schools movement is premised on the assumption that successful schools do exist and that other schools could be improved by adopting some of the practices found in effective schools. Berliner strongly recommended the study of expert teachers as a means of obtaining useful case material with potential applications in preservice and inservice courses for teachers. In the specific field of science education, Penick and Yager concluded that past case studies only highlighted the plight of science education and held little promise for stimulating improvements. Consequently, they advocated studies with a focus on successful science education as holding hope for improving practice. These ideas were incorporated into a project known as the Search for Excellence which began in 1982 under the sponsorship of the National Science Teachers Association, the Council of State Supervisors, the National Science Supervisors Association, and the National Science Board.

Because the Search for Excellence and other studies based on a similar philosophy had caused considerable excitement, optimism, and motivation among teachers, researchers in Australia and Israel decided to conduct somewhat similar research efforts. U.S. Search for Excellence, and the two other studies focused on the classroom practices employed by exemplary teachers rather than those of teachers of exemplary programs. These later studies were committed to intensive classroom observations of the exemplary teachers involved in the studies. The symposium will permit the first comparison and discussion of results in these three nations.

A CASE STUDY OF CONCEPTUAL TEACHING: TEACHING THE NECESSITY OF CONSERVATION REASONING IN PHYSICAL AND CHEMICAL CHANGES

Joseph J. Hesse III
Grand Rapids Junior College
Grand Rapids, MI 49503-3295

Charles W. Anderson
Michigan State University
East Lansing, MI 48824-1034

This paper presents a detailed case study of science teaching based upon a conceptual change teaching model. This paper documents how beginning chemistry students respond to teaching within a conceptual change framework and discusses the kinds of knowledge needed by the teacher to successfully implement these methods.

Three first-year chemistry classes at a midwest junior college were the subjects in an instructional unit on physical and chemical changes. The content for the instructional unit was taken from prior research into the naive conceptions of chemical change held by beginning chemistry students. The method of instruction was derived from a general model of learning proposed by Posner, Strike, Hewson and Gertzog.

The case study represents a four-day diary of a teacher and his students on their way to a conceptual change. The case study demonstrates ways in which students' reasoning changes over time. A discussion of the case study focuses upon implications for teaching and four kinds of knowledge needed by the teacher to help students overcome deep-seated naive conceptions in chemistry. The teacher must possess knowledge of his/her students, knowledge of chemistry, knowledge of teaching methods, and knowledge of classroom dynamics.

HUMP EFFECT AS OBSERVED DURING PROBLEM-SOLVING

Narendra Vaidya
Regional College of Education
Amjer, India

This study was undertaken to investigate certain aspects of thinking through the medium of problem solving among science students of adolescent age duly matched on intelligence and socio-economic status. One of its side aims was to study errors as they occur in solving a set of seventeen problems when presented individually in two sessions. These problems were mostly Piagetian in flavour and involved constant differences, summation, algebraic generalization, proportion, repeated structurings and restructurings, use of insight, proposing tests, combinational grouping, formulating problemistic situations, and stating as well as testing hypotheses.

A MATHEMATICAL MODEL OF COGNITIVE DEVELOPMENT

Shulamith G. Eckstein
Michal Shemesh
Technion - Israel Institute of Technology
Haifa 32000, Israel

A mathematical model is presented which describes developmental changes occurring with time. The model is applicable to a population which is categorized by hierarchically ordered developmental stages, and predicts the functional dependence upon age of the proportion of the population at a given developmental stage.

The model was compared with two experimental studies of Piagetian stages: one by Shayer & Wylam of 7093 British students aged 10 to 16, and one by Shemesh, Eckstein & Lazarowitz of 913 Israeli students aged 12 to 18. For analysis by the model of this paper, the subjects in these two studies were categorized into three Piagetian stages, (1) Concrete, (2) Transitional and (3) Formal. If f_1, f_2, and f_3 are percentages of students at each stage, then the model predicts that

$$f_1 = A \exp(-a_1 t) \qquad (1)$$

$$f_2 = B \exp(-a_2 t) - a_1 A \exp(-a_1 t)/(a_1 - a_2) \qquad (2)$$

$$f_3 = 1 - f_1 - f_2 \qquad (3)$$

where t is age, a_1, a_2 are parameters giving the rate of transition, and A and B constants of integration. The fit of Eq. 1 to the data of both studies was excellent. The fit of Eqs. 2 and 3 to the data of Shemesh, et al was also excellent with a Chi-square of only 3.9, for 8 degrees of freedom (p 0.85). A graphical comparison of the theory to the data of Shayer and Wylam appeared to be very good, but the Chi-square value was 48, for 10 degrees of freedom ($p<0.001$).

The model was also used to study the acquisition of formal operational schemata by adolescents. In this case, there are only two stages: Stage 1 consists of subjects who have not yet acquired the ability to perform a given Piagetian task, and Stage 2 those who have. The solutions for f_1 and f_2 are:

$$f_1 = A \exp(-at); \; f_2 = 1 - f_1$$

The model agrees well with a study by Lawson, Karplus and Adi of 507 students aged 12 to 20 in the United States and a similar study by Shemesh, Eckstein & Lazarowitz in Israel. The functional dependence upon age was found to be the same for 11 tasks involving four different formal operational schemata in both countries. These results give support to the "unity" hypothesis of Piagetian theory, that is, the hypothesis that the various schemata of formal thought appear simultaneously.

AN EVALUATIVE STUDY OF LEVEL ONE INSTRUCTIONAL VIDEODISC MATERIALS USED IN SCIENCE CLASSROOMS

Robert Sherwood
Ted Hasselbring
E. Jean Marsh
Peabody College
Nashville, TN 37203

The overall objective of the study was to evaluate, in actual classroom environments, the use of level one videodiscs and associated materials. Specific questions of interest were;

1. Would the use of videodisc-based materials provide "added value" to traditional classroom instruction?
2. How would teachers and students react to the use of the materials in classroom?

The use of optical-based media in a variety of subject areas and grade levels had increased in the last few years as the cost of the media and hardware to use it has decreased. Several different methods have been developed to use video materials. These have included direct instructional type video such as the ones that were used in this study. The effectiveness of these types of programs is of interest to administrators, teachers, and researchers and some evaluative studies have been done.

A school district in Eastern Tennessee was the partner in the reported study which was part of a longer two year study of videodisc implementation in a school system. The school system was in a rural area and had two K-12 schools of approximately the same general type which were designated the experimental and control school. Two different videodiscs were used in the experimental school: "Understanding Chemistry and Energy" and "Earth Science."

The control school teacher rated the questions on the chemistry videodisc posttest used with biology and physical science students as to their correlation to the topics that the teacher would have covered in the control classroom. Questions of different ratings were combined together and an analysis of covariance was undertaken on these data. Statistically significant results were found for students in both biology and physical science classes favoring the group that had used the videodisc.

A less controlled study was carried out on the use of the Earth Science disc with results showing that students increased their knowledge in this area through the use of the video materials. Interview data collected from both students and teachers indicated very positive attitudes towards the use of both the chemistry and earth science materials.

A LOGICO-STRUCTURAL, WORLDVIEW ANALYSIS OF THE INTERRELATIONSHIP BETWEEN SCIENCE INTEREST, GENDER, AND CONCEPT OF NATURE

William Cobern
Arizona State University
Phoenix, AZ 85069-7100

Jane Ellington
Daniel Schores
Austin College
Sherman, TX 75090

To increase the involvement of women in science, both as professionals and as enlightened citizens, we must ask what it is that currently bars their involvement. We have a clue in the recent Belinky et al book Women's Ways of Knowing which suggests that there is a distinctly feminine world view. As other studies have indicated worldview variations potentially interfere with science education, particularly when instruction proceeds unaware of the importance of fundamental epistemological structure in learning. The purpose of the research being reported here is to provide information about gender-related worldview structures among college students that can inform the instructional decision making process. This information is generated in a logico-structural investigation of the interrelationship of gender, interest in science, and concept of nature. The logico-structural approach to world view differs significantly from the monothematic approaches to world view based of Stephen Pepper's work, among others. The strength of logico-structuralism is its sensitivity to intra-worldview variation, and thus its avoidance of artificiality.

Worldview researchers primarily use a technique called "reading back." From observations one reads back to underlying presuppositions. In this study "concept of nature" was observed as college student responses to a direct question about nature. The preliminary results indicate that there are gender-related concepts of nature, indicating that women college students have presuppositions about nature that differ significantly from those held by men. Secondly, the results suggest that, among women college students, concept of nature is related to interest in science but not related among men students.

THE COMPARISON OF COGNITIVE DEVELOPMENT, SCIENCE PROCESS SKILLS, AND SCIENTIFIC ATTITUDE OF PRESERVICE TEACHERS WITH DIFFERENT SCIENCE BACKGROUND

Tien-Ying Lee
National Taiwan Normal University
Taipei, Taiwan, Republic of China

This was an ex post facto study to compare the differences in cognitive development, science process skills, and scientific attitude of preservice teachers belonging to two different programs and having different science backgrounds.

The results will be used as baseline data to evaluate the impact of the elementary preservice teacher education reform on the selection of students.

The sample size was 1486 which includes three categories with different science backgrounds. GALT, TIPS II, and Moore and Sutman's scientific attitude questionnaire were tested, modified, and retested and used as instruments in this study. Data were analyzed through frequency, correlation, and Kruskal-Wallis test.

The results indicated that 53.3% of the effective sample had reached the formal operational stage and 43.9% were in the transitional stage. Two groups of students, who had more science, had higher cognitive development and process skills. There was no significant difference in scientific attitude among groups. Reasoning ability and process skills were significantly correlated ($r=.54$, $p<.001$) which was consistent with previous studies. The higher percentage of formal operational students is reasonable since students who enter the teacher program are about the top 3-10% of students in the Republic of China.

TEACHER PREPARATION: THE ACADEMIC DEVELOPMENT OF PRESERVICE M' DDLE SCHOOL SCIENCE TEACHERS

Teresa M. Kokoski
Hsiao-Lin Tuan
Russell H. Yeany
Michael J. Padilla
University of Georgia
Athens, GA 30602

Currently little is known about the entry level knowledge and attitudes of students beginning preservice science teacher education programs. In addition, how and to what degree these students change as a result of their teacher education experiences also is an enigma. Significant changes, not merely acquisition of knowledge, in the areas of academic and professional

development are essential to transform a college student into a teacher. The objective of this paper is to report the status of preservice teachers' academic development as they complete one year of a middle school science teacher education program. Specifically, three areas of academic development addressed are: (1) development and retention of science content knowledge with an emphasis on common science misconceptions; (2) development of science process skills; and (3) development of pedagogical knowledge.

This study, following a one-year pilot study, evolved from the assessment of the revised program. In the program an emphasis was placed on increasing the amount of subject matter which stressed content appropriate to teaching in the middle grades. Three new courses in life, earth, and physical science were developed and implemented. Each new content course was also paired with a pedagogy course stressing content-specific pedagogy related to its matched content course. The courses were developed and taught by a team of scientists, educators, and classroom teachers.

Quantitative and qualitative methods were used in assessing the academic development of the preservice teachers. The preservice teachers demonstrated small gains, although not all significant, in content specific knowledge and science process skills knowledge. Several common misconceptions and common knowledge concepts were identified from the data. The development of pedagogical knowledge was not viewed by the preservice teachers as important as their development of science content knowledge.

This study provides some direction for the design of teacher education programs for middle school science. First, science content and pedagogical preparation are essential and considerations need to be given to the depth and breadth of this development in middle school science teachers. Also important are the expectations of preservice teachers and course instructors toward the course and the educational programs.

THE EFFECTS OF A PROJECT LEARNING TREE WORKSHOP ON PRE-SERVICE TEACHERS' ATTITUDES TOWARD TEACHING ENVIRONMENTAL EDUCATION

Dorothea E. Kunz
University of Idaho
Moscow, ID 83843

Patricia Farrell
The Pennsylvania State University
University Park, PA 16803

It was the primary purpose of this study to determine if a seven-hour Project Learning Tree (PLT) workshop had a positive effect on pre-service teachers' attitudes toward teaching environmental education. A secondary purpose was to revise the Science Attitude Scale into a reliable and valid scale to measure attitudes toward teaching environmental education.

The use of six principles, developed by Thompson and Shrigley to guide researchers when revising scales, aided in the development of the Environmental Education Attitude Scale. A five-point Likert scale was used to score subjects on 30 attitude statements. The scale consists of four subcomponents: comfort/discomfort, need, equipment/technology, and time. Scores on the subcomponents can be measured separately. Summated scores were used in the analysis.

One hundred and forty pre-service teachers enrolled in Science Education 458, an elementary science education course at The Pennsylvania State University, University Park, Pennsylvania were selected for this experimental study. There was a random assignment of equal numbers of subjects to an experimental group and control group.

During October, 1988, all of the pre-service teachers in the study were involved in a seven-hour environmental education workshop, PLT, offered by the Pennsylvania Department of Education. Participants in the workshop participated in PLT activities, taught at least one PLT activity, were introduced by state foresters to environmental education resources available in Pennsylvania and received a PLT curriculum guide with over 80 environmental education lesson plans.

Hypotheses were constructed for determining the effectiveness of the PLT workshop. Paired t-tests and t-tests comparing two independent mean total scores were used to indicate significant increases and differences in attitude scores. The level of significance was .05 for all tests.

The findings of the study include: (1) Pre-service teachers showed a significant positive change in attitude score on the Environmental Education Scale after participating in the seven-hour PLT workshop. (2) Pre-service teachers showed significant positive changes in their mean attitude score on three of the four subcomponents of the Environmental Education Attitude Scale. The cumulative score on the subcomponent scales for comfort/discomfort, need, and equipment/technology showed positive changes. The cumulative score on the time subcomponent did not show a positive change in attitude scale.

Based upon the findings and within the limitations of this study, it is concluded that participation in a PLT workshop results in a positive attitude change toward teaching environmental education. It can also be concluded that the Environmental Education Attitude Scale is a valid and reliable instrument that measures attitudes toward teaching environmental education.

CELL DIVISION: STUDENT MISCONCEPTIONS AND INSTRUCTIONAL IMPLICATIONS

Mike U. Smith
Mercer University School of Medicine
Macon, GA 31207

Recent studies in genetics problem solving recommend that the study of genetics should be closely tied to the study of cell division. Both subjects are widely recognized as difficult topics to teach and learn. In this study six college students enrolled in a genetics course were videotaped while they diagrammed mitosis and meiosis, and the videotapes were analyzed for evidence of misconceptions and other common errors. Additional evidence of misunderstandings was obtained from the analysis of pop quizzes, homework, and exams on the topic in an introductory biology class of 50 students.

First, four levels of understanding were identified among the student subjects, including an intriguing phase in which students know the initial chromosome number and the final chromosome number but resort to means-ends analysis to ascertain the intermediate steps. Second, a group of crucial but confusing genetics terms was identified. Third, students often erroneously conceive of cell fission in terms of their previous knowledge of reproduction, resulting in an erroneous conception of cell division as conservative of the parent cell. Fourth, almost all of the substantive errors identified relate to misunderstandings of the phenomena of chromosome doubling, chromosome separation, or chromosome pairing.

These findings suggest that meaningful student learning of cell division may be enhanced by an instructional emphasis on basic genetic terms and facts that are prerequisite to an understanding of cell division, an emphasis on chromosome number in the initial cell and the final cell products, and an emphasis on the three basic phenomena involved (doubling, pairing, and separating).

STUDENTS' CONCEPTIONS OF BASIC IDEAS OF THE SECOND LAW OF THERMODYNAMICS

Reinders Duit
Sofia Kesidou
University of Kiel
Federal Republic of Germany 2300

Thirty four clinical interviews with students of grade 10 (about 16 years old) were carried out in order to investigate conceptions in an area where few empirical studies have been conducted. The interviews were embedded into a qualitative research approach. Main attention was given to portraying ideas students with four years experience in learning physics developed in that field of phenomena.

The educational importance of the study may be viewed from two perspectives. The first one is of general nature. The careful analysis of students' argumentations in different tasks of the same content area revealed deep rooted students' difficulties to make use of concepts and principles they had learned in school. There is a strong tendency of students to rely on everyday explanations and not to use explanations learned in physics lessons. The study, therefore, reconfirmed findings of many other studies in a new content area. The second perspective concerns the second law of thermodynamics as a topic of science instruction. So far, this law is neglected nearly totally, especially in lower grades. Most students, therefore, do not learn a law which provides a very deep insight into the way "nature works" (namely the principle of irreversibility which states that all processes are running on their own in one direction only). They further do not learn a necessary prerequisite to understand the energy concept (which is given considerable attention in science instruction now). This is true because understanding of the principle of energy conservation requires a basic understanding of the principle of energy degradation (which is one of the many ways of stating the second law).

The results of the study confirmed findings of other studies concerning difficulties of learning the energy concept, the particle model and the differentiation between heat and temperature. They further provide support for the thesis the research is based on, namely that basic aspects of the second law may be learned already in lower grades.

ON THE INSTABILITY OF MISCONCEPTIONS: HOW STUDENTS FORM THEIR CONCEPT OF ISOMERISM

Hans-Jurgen Schmidt
University of Dortmund
Dortmund, Federal Republic of Germany

The study investigates (1) which misconceptions occur when students use the concept of isomerism for compounds of the molecular formula $C_4H_{10}O$, and (2) if these misconceptions are stable.

The data were collected in a paper-and-pencil test. The test was set to 5000 grammar school students from all parts of the Federal Republic of Germany. The results indicate that students are not satisfied with the criterion of identity of molecular formula. They expect, moreover, that isomers belong to the same class of compounds. If presented with detailed structural formulas of the isomers, students are inclined to think that isomers consist of similar molecular structure. The misconceptions are, therefore, not always stable. Tests only show how students respond to certain questions.

EFFECTS OF CONCEPT MAPPING ON MEANINGFUL LEARNING AND ACHIEVEMENT IN SECONDARY CHEMISTRY

Jimmy Daniel Allen
Calhoun High School
Calhoun, GA 30701

This study examined the effects of concept mapping on meaningful learning and achievement in chemistry and investigated how the student's attitude toward mapping affected his/her ability to master mapping strategies and acquire meaningful learning.

The design allowed for 53 subjects to be placed into two groups and randomly chosen to receive the treatment or controlled instruction for 15 weeks. All students received similar chemistry instruction. The treatment group was given mapping instruction, constructed maps, and completed attitudinal evaluations toward mapping on a regular basis.

Analysis of posttest results revealed no significant differences between groups on measures for meaningful learning and achievement in chemistry at the $p < .05$ level. Further analysis indicated no significant relationships among mapping scores and posttest performance. Analysis of variance results for successive, intermediate maps revealed a significant main effect at the $p < .05$ level. This evidence suggested that mapping performance improved with continued instruction. No significant difference existed between groups for posttest attitudes toward science and the regular classroom. No significant relationships existed among attitude toward mapping and meaningful learning, achievement, and final mapping scores.

For this study, concept mapping did not appear to enhance meaningful learning or promote higher achievement in chemistry. Concept mapping did not affect students' attitudes toward science or the regular classroom. Mapping performance was not related to meaningful learning and achievement scores. Students' attitudes toward mapping had no effect upon meaningful learning, achievement, or mapping performance. Attitudinal data toward mapping revealed mixed results with a general preponderance of negative views. Students experienced difficulty in constructing maps, but were able to master mapping after only 15 weeks of instruction.

MANIPULATION OF LOGICAL STRUCTURE OF CHEMISTRY PROBLEMS AND ITS EFFECT ON STUDENT PERFORMANCE

Mansoor Niaz
Universidad de Oriente
Estado Sucre, Venezuela

William R. Robinson
Purdue University
West Lafayette, IN 47907

It has been shown previously that manipulation of the M-demand of chemistry problems affects student performance, which suggests that manipulation of logical structure of chemistry problems could also lead to significant changes in performance. The objective of this study was to investigate the following: Given the opportunity for training, what is the effect of increasing (manipulating) the complexity of logical structure of chemistry problems on student performance, and to what extent can cognitive variables explain changes in performance? Results obtained show that: (1) even a small increase in the logical structure of a problem can switch the role of cognitive variables (M-capacity and formal reasoning) to the extent that increase in logical complexity outweighs the advantage students may have gained through training on a similar problem; (2) the use of algorithms and training on particular types of chemistry problems could lead to a situation in which formal reasoning is the only cognitive variable that explains variance in performance significantly; and (3) after having solved very similar problems on two different occasions with improving performance, the improvement is not retained if the logical structure of a third problem increases considerably. It was concluded that when dealing with significant changes in logical complexity of chemistry problems, developmental level of students is the most consistent predictor of success. A model for the qualitative analysis of logical complexity of chemistry problems is presented.

THE RELATIONSHIP BETWEEN STUDENTS' LEARNING STRATEGIES AND THE CHANGE IN THEIR CHEMICAL MISUNDERSTANDINGS DURING A HIGH SCHOOL CHEMISTRY COURSE

Saouma BouJaoude
Syracuse University
Syracuse, NY 13244-1070

There were two purposes for this study. The first purpose was to investigate the relationship between the learning strategies of students taking a chemistry course which emphasized breadth of coverage and their understandings of chemical change and the concept of burning. The second purpose was to investigate the differences in understandings between male and female students. Forty-nine high school students enrolled in two sections of Regents high school chemistry at a suburban school in New York state participated in the study. These students took a Misunderstandings Test, an Attitude Toward Chemistry Questionnaire, and a Learning Strategies

Questionnaire at the beginning of the 1988/1989 school year and the same Misunderstandings Test at the end of the same school year. In addition, the researcher attended classes for a total of 16 weeks to ascertain the type of teaching taking place in the two chemistry classes. The Learning Strategies Questionnaire was used to label the students as meaningful or rote learners which resulted in 24 meaningful learners and 25 rote learners. An analysis of covariance using students' attitudes and the pretest scores on the Misunderstandings Test as covariates and the end of the year scores on the Misunderstandings Test as the dependent variable (post-test scores) showed that there was a significant difference between the meaningful and the rote learners on the post-test scores ($F=9.98$, $p<.01$). However, there was no significant difference between male and female students ($F=3.25$, ns) and no significant interactions ($F=.082$, ns). A qualitative analysis of students' written responses on the second part of each question on the Misunderstandings Test showed that meaningful learners seemed to have developed coherent understandings of the concepts of chemical change and burning which were useful in their attempts to answer the questions on the Misunderstandings test which required more than rote learning.

Symposium

MULTICULTURAL SCIENCE EDUCATION: DEFINITIONS AND RESEARCH AGENDAS FOR THE 1990'S AND BEYOND

Mary M. Atwater
Joseph Riley
University of Georgia
Athens, GA 30602

Lowell Bethel
The University of Texas at Austin
Austin, TX 78712

Julia Clark
Texas A&M University
College Station, TX 77843

Steven Rakow
The University of Houston at Clear Lake
Houston, TX 77058

Multicultural education has been defined by a variety of people outside of science education. What are the possible definitions of multicultural science education? Is it a matter of attaching the word "science" in the appropriate places in the definitions given for multicultural education? One of the goals of this symposium is offer definitions of multicultural science education.

The other goal of this symposium is to delineate research agendas for multicultural science education. What research has been done in this area? What research areas need only additional research; what areas need beginning research?

Panel

INTEGRATING THE HISTORY AND NATURE OF SCIENCE INTO SCIENCE TEACHING

James D. Ellis
Biological Sciences Curriculum Study
Colorado Springs, CO 80903

This panel will be a forum for discussing the purpose, rationale, historical precedence, and recommendations for teaching the history and nature of science in K-12 school science. With support from the National Science Foundation (NSF), the BSCS in collaboration with the Social Studies Education Consortium (SSEC) is developing a framework for integrating the history and nature of science in school science and social studies programs. The project will gather information through reviews of the literature, commissioned papers, and expert advice, hold a meeting of an advisory committee to synthesize the information into a curriculum framework, and hold a writing conference to develop sample activities for teachers. The project will publish a monograph of the commissioned papers, a report of the curriculum framework, and a resource book of teaching ideas.

Project staff will develop a conceptual framework for education in the history and philosophy of science. Our intention in developing the framework is to influence pre- and in-service education and the development of materials for K-12 science and social studies. The conceptual framework will be designed to achieve two goals; first, to provide background and information about the history and nature of science and technology; and, second, to describe recommendations for incorporating the history and nature of science and technology into educational programs.

The project will commission several papers as background information for the meeting of the advisory committee, during which the curriculum framework will be developed. Two papers will be a general introduction to the history of science and technology; two will be a general review of the nature of science and technology; two will address the integration of the history and philosophy of science into school programs. Project staff will work with the authors of the commissioned papers to edit, revise, and prepare the papers for publication. BSCS will publish the papers as a monograph of readings on the teaching of the history and nature of science in-house or through a commercial publisher or professional society.

The project will develop a resource book for science and social studies teachers that will provide guidelines for curriculum and instruction, models for integrating the history and nature of science into extant curricula, and sample units and activities. We shall design the teacher resource book as a practical guide to teachers, curriculum supervisors, and administrators who want to revise their science and social studies curricula to include topics in the history and nature of science. BSCS will publish the teacher resource book in-house or through a commercial publisher or professional society.

The BSCS and SSEC materials will emphasize

- the integration of the concepts of the history and nature of science and technology into school science and social studies programs K-12.
- the contributions of women and minorities.
- activity-based approaches for science and social studies.
- an accurate presentation of the disciplines of both science and technology.
- an introduction to the nature of science and technology.

For the NARST panel, the project director will present the rationale and design of the project. The principal investigator will present the curriculum framework. Two consultants to the project will present their commissioned papers that provide a historical review and synthesis of the literature concerning the inclusion of the history and nature of science in science curricula. Following the presentations, the project director will open the topic up for discussion.

BELIEFS, ATTITUDES, AND INTENTIONS OF SCIENCE LEARNERS IN PUBLIC, PRIVATE, AND HOME SCHOOLS

Brian D. Ray
Seattle Pacific University
Seattle, WA 98119

The beliefs, attitudes, and intentions of public, private, and home school students (grades 3 to 8) with respect to laboratory and non-laboratory science were examined. The Theory of Reasoned Action was used to ascertain students' salient beliefs, correlations between constructs in the theory, relative weights of the determinants of intention, and the effect of type of schooling, gender, and grade level on the determinants of intention.

This exploratory study generated baseline information and used correlational analyses. The study's three stages included elicitation interviews with a subsample of students and construction of the instruments, a pilot study and refinement of the instruments, and final data collection and analyses. Multistage cluster sampling was used to select 377 public school students; 46 private school students, and 34 home school students were involved. Interviews with a random subsample of 20% of the subjects provided the salient beliefs upon which to base the construction of the instruments. Validity of the instruments was assured by close adherence to the Theory of Reasoned Action and the procedures outlined by the theory's authors. Readability of the instruments was adjusted to an appropriate level; the instruments were also read aloud to the subjects. It was assumed that students responded in a reliable manner.

RESEARCHING BALANCE BETWEEN COGNITION AND AFFECT IN SCIENCE TEACHING AND LEARNING

Richard Gunstone
John Baird
Chris Penna
Richard White
Monash University
Clayton, Victoria 3168 Australia

Attempts to improve the quality of classroom science teaching and learning are limited by inadequate understanding of the mechanisms of interaction among cognitive and affective aspects of the teaching/learning process. In a three-year research project, 33 teachers and over 1500 students from 4 schools collaborated with the authors to research the nature of such affective aspects as personal attitudes, beliefs, and concerns related to science teaching and learning, and their importance for determining levels of application and enjoyment, and consequent teaching/learning outcomes. both qualitative and quantitative procedures were employed, ranging from such broad probes as questionnaires completed by all participants, to

procedures involving protracted, intensive, shared reflection between individuals or small groups and the authors. These latter procedures included group-based collaborative action research and individual phenomenological wiring and reflection, over periods extending from two months to the whole three years.

Throughout the project, certain types of findings recurred across time, group, and type of procedure. These findings relate to the issue of the balance between cognitive and affective aspects of teaching and learning. The notion of challenge emerged as having a central influence on the participants' application, enjoyment, and success. From the project findings, challenge comprises a cognitive/metacognitive demand component and an affective interest/enjoyment component. Eight major features of a teaching/learning event were found to interact to influence these cognitive and affective components of challenge. The manner in which these eight features emerged from the collaborative research will be described. Challenge, and the interaction among its components, provides a conceptualization which illuminates many of the recurring findings, such as the commonly-observed drop in students' interest, application and commitment to science as they progress through secondary school. Effecting balance between the components of challenge was shown to enhance the quality of teaching/learning outcomes, and the extent of personal development.

In both its methodology and find ngs, the study resulted in increased understanding of the nature and importance of balance between cognition and affect in determining level of challenge, and thus teaching/learning approach, progress, and outcomes.

Challenge is considered a crucial notion for matching the processes of everyday science teaching and learning with the desired product of schooling - the effective, independent learner.

USING CONCEPTUAL CHANGE RESEARCH AND PROJECT 2061 TO IMPROVE SCIENCE ASSESSMENT PROGRAMS

Charles W. Anderson
Michigan State University
East Lansing, MI 48824-1034

Mozell Lang
Elizabeth Stevens
Michigan State Department of Education
Lansing, MI 48909

This paper describes efforts currently underway in Michigan to incorporate research knowledge into a statewide assessment and curricular support programs. These programs will include:

1. Science objectives written at the upper elementary, middle school, and high school levels. These objectives will be based on the Project 2061 report, Science for All Americans. They will emphasize activities involving the use of that knowledge in out-of-school contexts.
2. Achievement tests based on these objectives. The tests will use methods based on conceptual change research to develop thorough assessments of student understanding of selected topics, rather than sampling a wide range of objectives superficially. Tests designed for large scale assessment programs and for use by individual teachers will be developed.
3. Support materials that will help teachers understand the objectives, interpret their students' responses to the tests, and use the objectives and tests to improve their teaching.

Assessment programs, including both teacher-made tests and large scale assessment programs, are exerting increasing influence on science education policy and practice. Test results are used by administrators and legislators to evaluate the performance of teachers and students and to set policies. Teachers and students, in turn, interpret the contents of tests as signals about what is important to their superiors. Although many educators have been disturbed by the trend toward greater emphasis on testing, it appears that science testing programs are here to stay. This being the case, we should consider how they might exert a positive rather than a negative influence on teachers' professional knowledge and on science teaching and learning. It is the purpose of the project described in this paper to develop an assessment and support program that helps to accomplish this goal.

The development project draws on two bodies of research-based knowledge that are particularly relevant. The first of these is research on student conceptions of scientific topics; the second concerns science teaching and teachers' knowledge. This research reveals that inappropriate and ineffective patterns of science teaching are currently deeply embedded in science curriculum materials, in teachers' management practices, in the

nature of communication and student work in science classrooms, and in teachers' ways of understanding science and their students. No single program could solve all of these problems, but this research does reveal some critical problems that could be addressed by well-designed systems of student assessment and support materials for teachers. In particular, such programs could help teachers understand better how their students think about science, why scientific understanding is often difficult for them to achieve, and what sorts of experiences they need to achieve understanding.

Most science teachers would prefer to teach less content for a greater depth of understanding, but they are constrained from doing so by pressures for content coverage and by the absence of essential knowledge, tools, and materials. This paper describes one attempt to use research knowledge for the purposes of (a) developing a testing program that emphasizes understanding and (b) giving teachers access to knowledge and materials that will help them teach for understanding.

AN ANALYSIS OF THE RELATIONSHIPS OF FORMAL REASONING, SCIENCE PROCESS SKILLS, GENDER, AND INSTRUCTIONAL TREATMENT TO CONCEPTUAL SHIFTS IN TENTH GRADE BIOLOGY STUDENTS

Susan L. Westbrook
Laura N. Rogers
Edmund A. Marek
University of Oklahoma
Norman, OK 73019

Much of the recent focus in science education has been on the theoretical constructs and practical implications of conceptual change. History of science, cognitive theory, and alternative conceptions have been used as backdrops for the study of the child's conceptual movement away from naive beliefs about scientific phenomena. In the present study, conceptual shifts--any changes, positive or negative, in the way a child perceives a concept--are proposed as means of examining the process of conceptual change. The relationship of reasoning level, science process skills, gender, and instructional treatment to conceptual shifts in tenth grade biology students were compared.

The research utilized tenth grade biology students in a small midwestern city. Two teachers were involved in the study. Each teacher employed a different instructional method; teacher LC used the learning cycle and teacher EX taught by exposition. Student reasoning levels were evaluated using the Test of Logical Thinking (TOLT). The Test of Integrated Process Skills (TIPS) was used to measure the students' proficiency with science process skills. Five concept evaluation statements were used to determine the students' understandings of the concepts of diffusion, the cell, circulation, plant food production, and genetics. All instruments were used in a pretest-posttest format.

Examination of the data are presently underway. The analyses include (1) evaluating the correlations and interactions among the factors in the study and (2) comparing the nature of conceptual shifts with the instructional treatment the students received.

SCIENCE AS A VEHICLE FOR PROMOTING COGNITIVE DEVELOPMENT IN HIGH SCHOOL STUDENTS

Philip S. Adey
Kings College London
London, U.K. SW10 0UA

Classes of 11+ and 12+ year olds in eight secondary schools were given special intervention lessons intended to enhance their general cognitive skills. The interventions were based on the schemata of formal operational thinking, and employed notions of cognitive conflict, metacognition and bridging. An intervention lesson replaced one regular science lesson every two weeks, over a two year period. At the end of the two years, experimental classes showed greater gains in levels of cognitive development than control groups, but one year later any differences were no longer significant. In science achievement, however, although there was no immediate effect at the end of the intervention period, during the year following the interventions experimental groups performed significantly better than controls in the same schools. No far transfer effect was found to other school subjects. There were differences in the impact of the intervention program on pupils of different age and gender, and even within age/gender groups some pupils were affected far more than others. These differences may be accounted for in terms of learning styles. It is also argued that the schemata of formal operations form a more operationally viable framework for structuring the high school science curriculum than do process skills.

MISCONCEPTIONS ABOUT THE MOON HELD BY PRESERVICE TEACHERS IN TAIWAN

Meme Dai
William Capie
University of Georgia
Athens, GA 30602

Preservice teachers play an important role in elementary science education because elementary school children construct their concepts in mind based largely on what the teacher teaches. Therefore, the knowledge base and training of preservice teachers play an important role for elementary science education. Yet, science misconceptions held by preservice teachers exist. Preservice teachers soon become inservice teachers. The elementary school children in turn obtain the science misconceptions about the earth science. While studies indicate that a very low percentage of teachers in the United States have an academic background in earth science and astronomy, no investigation was focused on misconceptions about the astronomy held by students in Taiwan.

The moon is the most familiar object in the sky for Chinese people. The lunar phase has become a calendar that influences the daily life of Chinese people. Even though they acquire concepts about the moon from daily experience and in school, they retain notions that are incompatible with scientific concepts.

The purposes of this study are to (1) develop a multiple-choice test following the procedures of constructing items, pilot testing, and revision; and (2) use this test to identify the misconceptions about moonrise, lunar phase and physical phenomena of the moon.

The process of developing the test started with an effort to identify various understandings of the moon. A combined open-ended and multiple choice test was administered to 38 preservice teachers. The responses and comments were evaluated and used to construct a multiple-choice test in Chinese. Prior to administering the pilot test, each item was reviewed by a panel of experts to identify possible item construction errors. The test, containing 33 items, was pilot tested with 181 preservice teachers from three teachers colleges located in the north, middle, and east of Taiwan. The final version was used to assess preservice teachers among ten teachers colleges in Taiwan.

The preliminary findings show that preservice teachers hold misunderstandings and misconceptions about the moon. These results provide evidence that remedial action should be taken soon and enhancement of preservice teachers' background in astronomy is imperative so that both preservice teacher science eduction and elementary school science education will be improved. Further study on cross-culture and cross-age studies on misconceptions about the moon is appropriate.

THE SCIENCE PREPARATION OF ELEMENTARY TEACHERS

Linda R. DeTure
Eileen Gregory
Brian Ramsey
Rollins College
Winter Park, FL 32789

The subject area in which elementary teachers are the least confident and prepared to teach is science. The purpose of this project is to develop an effective model to better prepare teachers by enhancing their content background, and helping them teach inquiry-oriented science.

Three departments (Biology, Chemistry, and Education) combined efforts to redesign the science program for elementary teachers by developing and implementing a new sequence of science courses. The first content course integrates chemistry with biology emphasizing the interdisciplinary nature of science. A companion methods course facilitates the student's ability to use process skills and to apply the concepts in the content course.

To assess the first two pilot courses a pretest/posttest design was used with a nutrition class, the course elementary majors usually took, as a comparison group. Both content and attitude data were collected. Anecdotal records were kept and all classes were audiotaped. ANOVA showed that the treatment group had significant posttest gains for the cognitive test, but that the comparison group did not.

In regard to attitudes, no group was significantly different in their attitudes toward science and their attitudes did not become more positive after having either of the science courses. The elementary education majors had a significantly more positive attitude toward science teaching, but none of the groups were more positive after the classes. A number of revisions were made both during and after the first set of classes and have been implemented in the second set of classes.

SCIENCE TEACHING/LEARNING IN NEW YORK CITY SECONDARY SCHOOLS - A FOCUS ON RESEARCH NEEDED IN URBAN COMMUNITIES

Pamela Fraser-Abder
Andrew Apicos
Marlene Licciardello
Salvatore Maugeri
Maria Obregoro
Karina Sweeney
New York University
New York, NY 10003

The focus of the symposium is the status of science teaching and learning in New York City, an urban community, which caters to an extremely diverse student population and the research needed to improve science teaching and learning in such a community. This research was conducted to provide students with an insight into the realities of teaching/learning science in an urban setting.

The areas to be discussed in the symposium include

1. The secondary science curriculum:
2. Projects aimed at making science relevant;
3. Urban students:
4. Urban science teachers:
5. Strategies for improving science teaching:
6. Research needed to improve science teaching/learning under the conditions described.

Several areas need to be researched if we are to improve science teaching/learning in New York City schools. These include:

1. research aimed at improving science achievement among minority groups;
2. research aimed at increasing the number of women engaged in science careers;
3. research aimed at increasing the number of minorities engaged in science teaching and acting as role models for minority students; and
4. research aimed at increasing the number of students who do science at high school.

Data for the symposium were collected from 400 students, 25 science teachers, science teachers associations, the Department of Education, journal articles, and science educators.

GENDER DIFFERENCES IN SCIENCE: WHERE THEY START AND WHERE THEY GO

Dale Baker
Arizona State University
Tempe, AZ 85287-1911

This research investigated differences in attitude toward science by gender and grade level. One hundred and forty-nine students in kindergarten through twelfth grade were interviewed using a semi-structured protocol. The interviews were coded for re-occurring themes and responses. Inter-rater reliability was established at 100% agreement. Responses in the coding categories were counted and a discrimanant analysis was performed on the data using eight groups; males and females in grades K-3, 4-6, 7-9 and 10-12. The analysis suggested six categories of variables that maximized the differences among groups. These categories were (1) content and courses, (2) instructional strategies of teachers, (3) students' preferred instructional strategies, (4) future plans, (5) the concept of science and scientists, and (6) stereotypes. Differences were found for gender, grade, and gender by grade. At the elementary level students' recall of the topics they studied were gender stereotyped. Males remembered rocks, weather and space, while females remembered plants, animals and sea life. These early preferences were mirrored in high school course taking behavior. Females, regardless of grade level, remembered the teacher using passive instructional strategies such as worksheets and males remembered active instructional strategies such as group work. All students said that they preferred active instructional strategies. Elementary students expressed a strong dislike for using a science textbook. As early as K-3, males planned to study more science while females did not. Females said science was boring. This response increased in strength as students moved through school. By 7th grade, females also felt that science was repetitious. Males, K-9, and females 10-12, said that males liked science more than did females. Males, K-9, also said that males were more likely to have an aptitude for science, while females, K-6 and 10-12, said that females were more likely to have an aptitude for science. Although the trends are not continuous through the grades, there was a tendency for the students to separate ability from affect.

WEAVING A NETWORK OF EARLY SUPPORT FOR GIRLS IN SCIENCE: EMPOWERING ELEMENTARY TEACHERS

April L. Gardner
Teresa McDevitt
Mark Constas
University of Northern Colorado
Greeley, CO 80639

A novel course with goals to sensitize students to inequities in mathematics, science, and technology-related fields; to explore possible causes of those inequities; and to develop and practice teaching strategies to help minimize the inequities was developed and evaluated with 65 prospective elementary teachers. Students enrolled in the course, Equity Issues in a Technological Society, for the Fall semester, 1988. They examined current statistics on the numbers of women, minorities, and physically disabled persons in science-related areas, studied research on the treatment of boys and girls in elementary science and mathematics lessons, and developed teaching strategies which would encourage students of all genders, racial/ethnic groups, and physical disability status in science and mathematics. Quantitative as well as qualitative data indicated that the course attained its goals, at least over a short-term period of time. Two instruments, the Occupational and Educational Information Instrument, and the Teacher Behavior in the Classroom, were developed to measure students' knowledge of the occupational and educational status of females, minorities, and physically disabled in technological fields and their knowledge of teachers' interactions with boys and girls in the classroom, respectively. There was no statistically significant difference between mean scores on the instruments for the Equity Issues group and a control group at the beginning of the semester; however, a significant difference in favor of students who had completed the course was found at the end of the semester. Furthermore, interviews with Equity Issues and control group students indicated that students who had completed the course did understand the equity concerns which exist for teaching mathematics and science and were able to suggest specific strategies for stimulating the interests and skills of underrepresented groups in mathematics and science. The control group students did not exhibit this sophisticated understanding of the issue.

GENDER DIFFERENCES RESEARCH AND FEMINIST RESEARCH: PROSPECTS FOR THE FUTURE

Nancy W. Brickhouse
University of Delaware
Newark, DE 19716

Considerable research has been undertaken to assess the nature and magnitude of the difference between men's and women's participation and achievement in science. Research programs have tried to elucidate explanations for the differences in achievement by examining differences in course enrollments, differences in informal learning opportunities,

differences in motivation, and differences in cognitive abilities. Recent classroom-based research has also described the differential treatment of boys and girls in science classrooms.

Many of these studies have provided valuable insights into the status of women in science and the barriers they must overcome to be successful in science. Others have tried to explain differences such that the status quo is rationalized rather than challenged. The thesis of this paper is the research oriented toward elucidating differences in the genders may best be guided by feminist theories, which challenge the status quo.

The last four years' issues of Science Education, Journal of Research in Science Teaching, and International Journal of Science Education were examined to elucidate major areas of research in gender differences. These areas include: (1) cognitive abilities, (2) achievement in various subject matters and grades, (3) teacher effectiveness, (4) motivation, and (5) classroom practice. This research was summarized and its prospects for improving the status of women in science characterized.

To provide a feminist direction for future research on gender differences the following questions were addressed: (1) How do we define success and is this definition gender-neutral? (2) Are measures of cognitive abilities gender-neutral and educationally important? (3) How can research in science education better address the problems associated with teaching girls the concepts in a discipline that was constructed largely by men? (4) How can research on teaching benefit from examining how the nature of women's work differs from men's work?

INDEX

NAME	PAGE(S)
Abegg, Gerald	125
Abell, Sandra K.	99
Abraham, Michael R.	49
Adey, Philip S.	166
Ajewole, Gabriel	104
Allen, Jimmy Daniel	156
Alting, Annita	9
Anderson, Charles W.	147, 164
Anderson, O. Roger	5
Anderson, Ronald D.	55
Andriesse, Clive	132
Apicos, Andrew	168
Arditzoglou, Sophia Yani	33
Atwater, Mary M.	70, 159
Ault, Charles R., Jr.	3
Baird, J. Hugh	67
Baird, John	162
Baker, Dale	170
Barman, Charles R.	137
Barnes, Lehman W.	132
Barnes, Marianne B.	132
Barufaldi, James P.	15
Bay, Mary	10
Beichner, Robert J.	41
Ben-Chaim, David	60
Bennett, Elizabeth M.	41
Berg, Craig A.	40
Berger, Carl F.	21
Berlin, Donna F.	129
Bethel, Lowell	159
Bettencourt, Antonio	44
Biermann, Carol A.	83
Bitner, Betty L.	66
Black, Carolyn B.	51
Bonnstetter, Ronald J.	145
Borko, Hilda	35
BouJaoude, Saouma	157
Brickhouse, Nancy W.	171
Briscoe, Carol	23
Brody, Michael J.	106
Bryan, Tanis	10
Butts, David	70
Bybee, Rodger W.	19, 102

NAME	PAGE(S)
Callison, Priscilla L.	94
Capie, William	167
Carlsen, William S.	12
Champagne, Audrey B.	19
Chang, Edith Yi-Tan	42
Changar, Jerilynn	136
Charron, Elisabeth	50
Chiappetta, Eugene L.	120
Clark, Julia	159
Clermont, Christian P.	35
Cobern, William W.	116, 150
Cohen, Michael R.	3
Coleman, Dava C.	91
Connery, Mary A.	74
Constas, Mark	171
Contreras, Armando	8
Cornett, Jeffrey W.	12
Correll, Jeffrey	58
Cossman, George W.	36
Craig, Madge T.	69
Crawley, Frank E.	33, 51, 91
Crews, William E. Jr.	131
Crocker, Betty	119
Cronin-Jones, Linda	96
Czerniak, Charlene M.	53
Dagher, Zoubeida	36, 46
Dai, Meme	167
Danzl-Tauer, Lynnette	116
DeTure, Linda R.	168
Doan, Robert L.	115
Dori, Yehudit Judy	99
Duit, Reinders	123, 154
Dunkhase, John	46
Ebert-Zawasky, Kathleen	125
Eckstein, Shulamith G.	148
Edwards, Billie	21
Ellington, Jane E.	116, 150
Ellis, James D.	1, 160
Engler, Pamela	101
Enochs, Larry G.	51, 93

NAME	PAGE(S)
Farragher, Pierce	84, 100
Farrell, Patricia	152
Fillman, David A.	120
Flick, Larry	64
Ford, Cindy	94
Fraser-Abder, Pamela	60, 168
Fraser, Barry J.	38, 145
Furuness, Linda	3
Gabel, Dorothy	81
Gagliardi, Frank	59
Gallagher, James J.	44, 55, 145
Gallard, Alejandro J.	103
Galon, Miri	31
Gardener, Cathy	88
Gardner, April L.	171
Gess-Newsome, Julie	85
Giddings, Geoff J.	38
Glasson, George E.	75, 90
Glenn, Nancy D. Green	121
Glynn, Shawn M.	113
Good, Ronald	34
Gooding, C. Thomas	74, 114
Goulding, Phil	1
Govindarajan, Girish	94
Gregory, Eileen	168
Griffiths, Alan K.	38
Gunstone, Richard	162
Gurney, Bruce	110
Haidar, Abdullateef H.	49
Hairson, Rosalina	70
Hale, James B.	10
Hall, Donald A.	63
Hannigan, Michael R.	1
Hartshorn, Robert L.	135
Hasselbring, Ted S.	76, 149
Haury, David L.	139
Hauslein, Patricia L.	34
Hesse, Joseph J. III.	147
Hofstein, Avi	38, 145
Holland, Cynthia T.	96
Holman, Jere R.	101
Horak, Virginia M.	89
Horak, Willis J.	89
Howe, Ann C.	87
Huang, Hui Ju	46

NAME	PAGE(S)
Ismail, Zurida	98
Iuele, Patricia	56
Jackson, David	21
Jegede, Olugbemiro Johnson	11, 104
Jones, Gail	32
Jorde, Doris	103
Joslin, Paul	123
Kephart, Michelle M.	74
Kesidou, Sofia	154
Kim, Chan-Jong	15
Kinnear, Judith	126
Kitchener, Richard F.	78
Koballa, Thomas R., Jr.	91
Kokoski, Teresa M.	151
Krajcik, Joseph S.	35
Kuerbis, Paul J.	19
Kuiper, Wilmad A.J.M.	9
Kumar, Lavinia	57
Kunz, Dorothea E.	152
Lalik, Rosary V.	90
Lang, Mozell	164
LaRussa, Annette	98, 111, 133
Lavoie, Derrick R.	142
Lawson, Anton E.	6, 78
Lazarowitz, Reuven	31
Lederman, Norman G.	17, 85
Lee, Tien-Ying	151
Lenk, Cecilia	1
Licciardello, Marlene	168
Lind, Karen K.	141
Lindauer, Ivo	123
Liu, Chin Tang	46
Lord, Thomas R.	83
Lorsbach, Anthony W.	23, 45
Marek, Edmund A.	165
Markovits, Paul S.	136
Marsh, E. Jean	76, 149
Martens, Mary Lee	29
Mason, Cheryl L.	80
Matthews, Charles	46
Maugeri, Salvatore	168
McCurdy, Donald	144
McDevitt, Teresa	171
McD Rowland, Paul	52

NAME	PAGE(S)
Melear, Claudia	128
Merkle, Dale G	38
Mintzes, Joel J.	14
Mitchener, Carole P.	55, 136
Morris, Edgar D. Jr.	75
Mosothwane, Modise	97
Muscella, Deborah	55
Naimoli, Alan	58
Nelson, Ramona	135
Niaz, Mansoor	78, 157
Norman, John T.	48
Norman, Obed	46
Novak, Joseph	78
Obregoro, Maria	168
Okebukola, Peter	11, 104
Padilla, Michael	19, 151
Pallrand, George	58
Paltzer, Arnold	73
Pedersen, Jon E.	90, 144
Penna, Chris	162
Perry, Deborah L.	3
Piburn, Michael D.	118
Pirkle, Sheila	58
Pizzini, Edward L.	15
Pollard, Rebecca J.	95
Powell, Janet C.	1, 102
Powers, Don	94
Prather, J. Preston	135
Rakow, Steven	159
Ramsey, Brian	168
Ray, Brian D.	162
Reed, Barbara	119
Rice, Diana C.	81
Riggs, Iris M.	51, 93
Riley, Joseph P.	77, 97, 159
Robertson, William C.	102
Robinson, William R.	157
Rogers, Laura N.	165
Rogg, Steven R.	143
Romance, Nancy R.	27
Roth, Wolff-Michael	129
Rubba, Peter A.	106, 107

NAME	PAGE(S)
Sarinsky, Gary B.	83
Scantlebury, Kathryn	117
Scharmann, Larry C.	93, 138
Schell, Robert E.	74, 114
Schmidt, Hans-Jurgen	155
Schores, Daniel M.	116, 150
Schuyler, Jennifer	67
Shaw, Edward L. Jr.	115, 119
Shedd, Jill D.	137
Shemesh, Michal	148
Shepardson, Daniel P.	15
Sherwood, Robert D.	76, 149
Shymansky, James A.	46
Shyu, Yu-Jiing	64
Simmons, Patricia E.	70, 88, 126
Simpson, Patricia R.	71
Smith, Bruce	140
Smith, Mike U.	154
Stahl, Robert J.	67
Staver, John R.	10
Stevens, Elizabeth	164
Stuessy, Carol L.	95
Sudweeks, Richard	62
Sullenger, Karen	25
Swami, Piyush	3
Sweeney, Karina	168
Swift, J. Nathan	74, 114
Swift, Patricia R.	74, 114
Sydney-Smith, Ian	24
Taddonio, Thomas E.	48
Tamir, Pinchas	6
Teates, Thomas G.	75
Thompson, Ertle	41
Tobin, Kenneth	23, 55, 145
Tolman, Richard R.	62
Treagust, David F.	24, 123, 145
Tuan, Hsiao-lin	133, 151
Tull, Delena	71
Tung-Hsing, Hsiung	77
Ulerick, Sarah L.	23, 45
Vaidya, Narendra	147
Van Den Akker, Jan J.H.	27
Vasu, Ellen S.	87
Vitale, Michael R.	27

NAME	PAGE(S)
Waick, Donna	114
Wallace, Josephine D.	14
Watson, Scott B.	32
Wavering, Michael J.	109
Westbrook, Susan L.	165
White, Arthur L.	129
White, J.E.	113
White, Richard	162
Wiesenmayer, Randall L.	106, 107
Wright, Emmett	94
Yager, Robert E.	145
Yeany, Russell H.	151
Yeotis, Catherine G.	12
Yochim, Jerome M.	99
Yore, Larry D.	69
Young, M. Jean	102
Zielinski, Edward J.	140
Zoller, Uri	60

199